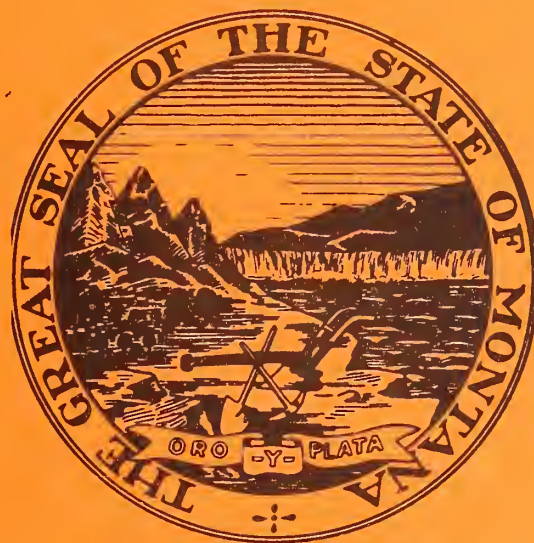


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Maintenance & Equipment Division
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Introduction

This manual was compiled as a primary information source. It does not profess to be the complete answer to asphalt pavement maintenance situations. It is a basic reference volume on causes and cures for asphalt pavement failures.

The processes described in this manual are proven established techniques. There are more modern techniques and equipment that when available allow you to do a better job with greater ease. There are other valid procedures and techniques that may not appear in this manual. This information gives you a base on which to build with your knowledge and experience.

This manual does not constitute Montana Department of Highways policy. Some of the repair techniques illustrated cannot presently be applied by Field Maintenance forces, due to equipment limitations and availability. The weather also makes some repairs impossible, so that temporary measures have to be applied until conditions are more favorable for more permanent techniques to be applied.

A bibliography will be provided in Appendix C. The publications mentioned there can be purchased from The Asphalt Institute. They provide in-depth information on techniques, specifications and uses that you might wish or need to know.



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TRAFFIC GROWTH

Traffic is still growing at very rapid rates and the weight of trucks has changed dramatically in the past 20 years. Many local roads were never designed or built to handle today's traffic. From 1960 to 1980, motor vehicle registrations increased by 75 million while the population grew by only 30 million.

With the decline of the railroads in many areas of the country, our roads and streets have become rubber-tired freightways. The number of trucks more than tripled from 9 million in 1969 to over 30 million in 1980, a trend that is expected to continue to the year 2000.

Compounding this problem even further is the weight of today's trucks. The average fleet truck in 1960 weighed about half of what the average fleet truck weighs today, and depending on the pavement thickness, this increase can have almost significant effect on pavement life. Estimates range from a decrease of 10% in design pavement life on thick pavements to reductions of 90% on thin pavements. Many of our local roads were never designed for the truck traffic they are experiencing today.

Roads and streets are the single public facility which practically every taxpayer uses every day. Unlike other facilities or public buildings he may occasionally visit, roads and streets get a physical and visual rating every day of the year. They are, in brief, the most visible public facility that affects every citizen's safety, comfort and economy each day of the year.

The public relations value of providing timely preventive maintenance and strengthening overlays for increased traffic should be obvious. The efficient, cost-effective use of material for new overlays contrasts sharply with the inefficient and wasteful practice of continually filling potholes. Preventive maintenance is always cheaper, or, as one observer put it, "we never seem to have the money or time to do it right in the first place but we always seem to have the money and time to do it over and over and over."

WEATHER

Weather is the most significant contributor to the severity of the pothole problem. Excess water beneath the pavement weakens the soil tremendously, particularly when the ground starts to thaw in the spring and is saturated. The pavement can crack and easily break into pieces if enough heavy loads pass over the pavement in this weakened condition.

The asphalt in the pavement is thermoplastic and becomes very brittle at low temperatures. Therefore, when it is subjected to cold conditions with weak ground support, it will crack at an accelerated rate. Pavements can be built to minimize this effect but many existing pavements were never designed for this condition, particularly on local roads.

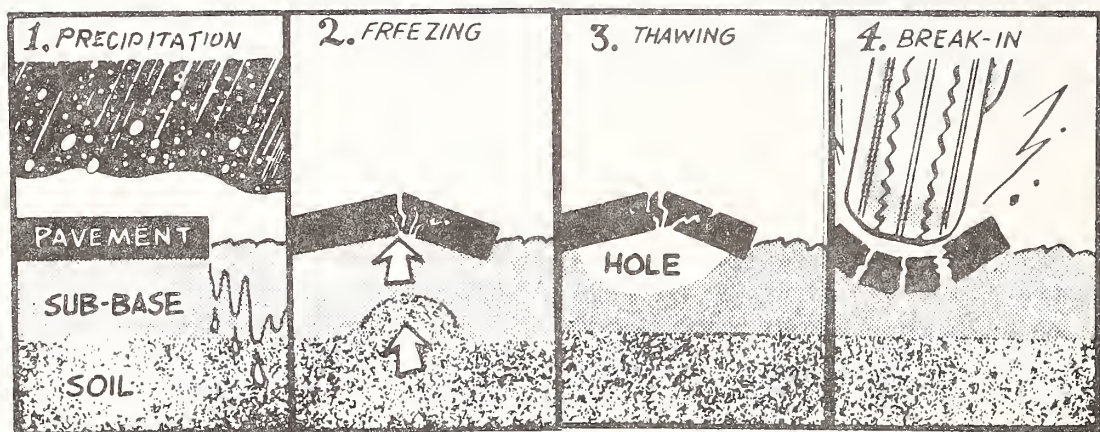
POTHOLE OCCURRENCE

Most potholes will result from one or more of the four main causes:

1. Roads that have insufficient thickness to support traffic during winter/spring thaw cycles without localized failures.
2. Poor drainage, which will usually cause failure in combination with thin pavements, but can also affect thick pavements and new overlays.
3. Failures at utility trenches and castings.
4. Miscellaneous paving defects and cracks left unmaintained or unsealed from water intrusion.

HOW POTHOLES DEVELOP

A pothole develops when two factors are present at the same time - water and traffic. This could almost be called the cardinal rule of pothole development, because without water and traffic present at the same time, potholing simply won't develop. Exceptions to this rule do not exist!



Factors leading to pothole failure by fatigue.



1. Fatigue failure is caused by excessive flexing of the pavement which occurs most commonly and sometimes on a grand scale on thin pavements when excess water is in the base. Meltwater formed during the spring thaw or water from poor drainage weakens the soil under the pavement. Then the pavement excessively flexes up and down with traffic until it starts to crack and break in several spaces.

Fatigue failure produces what is considered to be the classic pothole (a bowl-shaped crater) which can occur with very little warning or prediction. If enough traffic passes the pavement while excess water is present, it will eventually pothole. Thinner pavements (under 3-in.) are more prone to this type of potholing because the pavement disintegrates into very small, 1- to 2-in. pieces that traffic can easily dislodge. This type of failure is most common in the spring period, although it can occur in the summer and fall after heavy rains.

As the pavement approaches a thicker dimension, somewhere between 3 and 4 inches, the pavement may also crack by the fatigue mechanism described earlier, but generally the internal forces that cause the slab deformation diminish and prevent breakdown into very small pieces that can easily pop out. Fatigue failure in thick pavements works like a very thick jigsaw puzzle. The pavement may crack substantially and become very rough, yet it will stay safe and serviceable for a long period of time. Rarely will a fatigue failure occur on a 4 inch or thicker pavement and lead to potholing without plenty of notice that maintenance is needed.

2. Raveling failure is significantly different but, again, occurs only when traffic is present and water actually washes

away the adhesive asphalt films (stripping) that hold the stone aggregate together. This leads to a gradual raveling away of the stone particles. This condition occurs when the water has a chance to permeate a pavement that lacks sufficient density to prevent water penetration. Raveling may also occur at edges or openings in pavements such as at cracks and joints or other defects that have not been maintained by timely sealing.

The potential for pothole development by raveling can readily be predicted or monitored as telltale signs are quite obvious and exist for a long period of time (2 to 5 years) prior to disintegration due to potholing. Following a rainstorm, potential raveling locations always stay damp or wet-looking for long periods of time after the rest of the pavement has dried out.

DRAINAGE

Every engineer is expected to know that drainage is the most important aspect of highway design.

Problems concerning drainage are generally associated with the following:

1. Standing water in ditches.
2. Soils with poor drainage - cracks in the surface of roads.
3. High water tables and seepage.
4. Frost penetration - heaves and cracking of pavement.
5. Subgrades with low permeability.
6. Pumping under traffic.
7. Freeze-thaw deterioration.

These problems may occur together or in various sequences. It is likely that a combination of problems is present in failure areas.

DITCHES AND DRAINAGE

Standing water in ditches and storm drains is usually a sign of poor design or poor maintenance. There are areas where the

surrounding area is flat and where standing water cannot be avoided. In these areas, the cross section of the road must be built with enough height of the correct materials above the water to provide strength and to prevent frost damage.

Too often, standing water occurs because of poor maintenance. Ditches become filled with growth and debris above the maximum grade and slope permitted. A normal program of inspection and removal of debris is mandatory for the maintenance of any road.

Partially or completely blocked drains and culverts are a major culprit contributing to the problem of filled ditches. When a culvert silts, the upstream ditch will also become filled. A regularly scheduled program to clean storm drains is a must in the maintenance program for cities, towns and rural areas.

Maintenance of drainage features offers the greatest return for most road programs in the spending of annual funds for maintenance of roads. Unfortunately, drainage maintenance is a low-profile task that is often not immediately visible and is often the first to be cut from local budgets.

Poorly maintained shoulders also allow water to penetrate the pavement section. Raveling and potholing of the shoulders is a frequent problem.

CROWN AND CROSS SECTION

The crown and cross section of roadways usually get the greatest attention from designers and engineers. Frequently, problems occur with all roads and highways at areas where low spots occur. Potholes frequently appear in low spots: a) at curb lines, b) at intersections where roads with slightly different cross-slopes intersect.

Cracks in the pavement surface must be sealed. A regular program of surface treatment and sealing cracks offers long-term benefits for many urban and rural roads. In areas where surface treatments are undesirable, a 1/2- to 3/4-inch thick asphalt concrete overlay offers long-term benefits, particularly where the additional strength is not required.

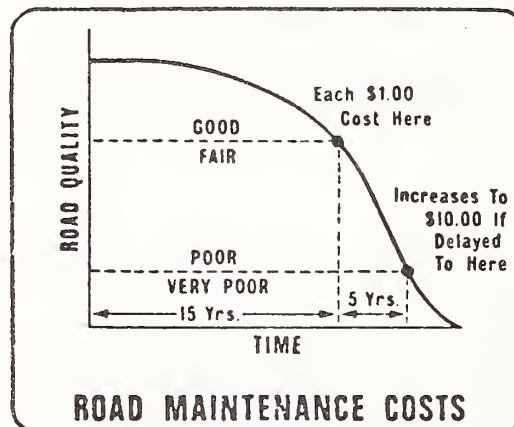
PREVENTIVE MAINTENANCE

Preventive road maintenance must be an annually planned program to preserve, repair and restore a system of roadways and its elements. Roadway elements include travelway surfaces, shoulders, roadside growth, and drainage facilities (including

gutters, ditches, and pipes). A policy of only repairing potholes and blocked drains is not a maintenance program. Unfortunately, due to slashed budgets or a lack of foresight, many departments can do little more today.

When potholes develop, prompt action is required to correct the defect before wheels and water combine to increase the size and severity of the defect. Most potholing develops in the spring breakup period before frost has completely disappeared or during brief winter thaws. Hot mix should be used whenever possible for best results. The success of pothole repairs can be directly related to good preparation of the hole and the amount of compaction attained.

One chart from a paper by M.J.E. Sheflin, Transportation Commissioner of Ottawa-Carleton, Canada, succinctly tells the story of the economic value of timely maintenance. This dramatically shows that maintenance must be a continuous process treating a certain percentage of the system each year.



Economics of timely maintenance

UTILITY CUT CONTROL

In any city or town where underground utilities exist, there also exists a tremendous potential for pothole development related to cuts in the pavement. Whether or not a community has a pothole problem related to these cuts simply depends on the degree of quality control it demands from utilities and contractors.

PATCHING OF NORMAL POTHoles

A comparison of effectiveness for different techniques of pothole repair is shown in a value engineering study reported in 1976 by Louis O'Brien, Director, Bureau of Highway Maintenance, of the

Pennsylvania Department of Transportation. Let's look at the costs. This study, which is summarized in more complete detail in the following table, shows that patching potholes the wrong or expedient way costs \$300/ton, while doing it the right way costs \$60/ton or one-fifth the cost.

One can easily see that the annual cost to make pothole repairs correctly is in the range of one-fifth the cost to do it poorly or expediently. The basic problem, restated for emphasis (as it is also the key to the solution), is that they simply don't have the time or decent conditions.

Comparison of costs for different methods of pothole repair (from O'Brien 1976)

<i>No.</i>	<i>Description</i>	<i>Equipment</i>	<i>Tons in place per shift (7.5 hrs)</i>	<i>Cost per ton of material in place (\$)</i>	<i>Life of patch (months)</i>	<i>Annual cost per ton (\$)</i>
1.	Fill hole in one lift with mixture, and compact by hitting the patch with the back of a shovel twice. No effort made to clean or shape the hole, and no tacking of the exposed surfaces of the hole.	Dump truck Shovels	18.0	25.64	1	307.68
2.	Same as no. 1, except compaction is performed with the tire of the dump truck.	Dump truck Shovels	12.0	31.80	2	190.80
3.	Shape the area to be patched with an axe and sledge, remove loose asphalt with mattock, sweep area clean, tack the exposed surfaces of patch area, shovel in material and level with lute. Compact with wacker (vibratory compactor) and seal edges with tack oil and #1B stone.	Dump truck, Pickup, Heating kettle, Wacker, Axe, Sledge, Brooms, Mattocks	6.0	63.29	7*	63.29
4.	Same as no. 3, except a pup roller is used for compaction.	Dump truck, Pickup, Heating kettle, Pup roller, Axe, Sledge, Brooms, Mattocks	7.0	61.41	7*	61.41
5.	Same as method no. 4, except the area to be patched is shaped with a pavement breaker.	2 Pickups, Dump truck, Heating kettle, Air compressor and Pavement breaker, Pup roller, Brooms	7.0	65.22	7*	65.22

* For methods 3, 4 and 5 it will be assumed that failure will occur after 12 months, though in all probability patch life will extend beyond one year.

Pothole maintenance is a continuing problem and usually appears at a time when it is difficult to make permanent repairs. Too often the solution consists of a few shovelfuls of premixed asphalt patch material deposited in the hole with the hope that traffic will provide compaction. To achieve proper pothole maintenance it is necessary to take into consideration the following important items:

1. Weather
2. Trained personnel
3. Use of suitable materials
4. Safety

1. Weather

Best results will be achieved by scheduling repair work during dry, warm weather. However, the problem is usually most urgent during wet weather. This requires greater care and proper equipment to ensure success. Personnel assigned to pothole repairs should be aware of material limitations during cold and wet weather.

2. Training of personnel

It is easy to blame material for failure, but even the best available materials will fail when improperly used. Therefore, the most important item for successful pothole maintenance is providing sufficiently trained personnel to identify the problem and to apply an appropriate technique to make the repair.

3. Materials selection

Patching may be done with cold mix asphalt materials, hot mix asphalt materials, concrete, or other suitable patching material.

4. Safety

Pothole patching is usually done under traffic conditions. The safety of working personnel and the traveling public is of utmost importance. Maintenance personnel should work from the center of the road to the shoulder to avoid stepping into the opposite traffic lane and should be equipped with reflective clothing.

PATCHING PROCEDURES FOR OTHER TYPES OF FAILURES

1. Pavement that lacks density

When an entire layer of paving material lacks proper density, it will show up early in the pavement's life by staying damp for a long period of time after the rest of the pavement dries following wet weather. The next stage will be gradual raveling of the aggregate in the mix.

If the area is small and not allowed to get too deteriorated, it can be spotted by maintenance crews and sealed with a slurry of liquid asphalt and fine aggregate. Severe cases should be removed and replaced with new material.

2. Joints

Longitudinal joints between paver passes may open up if not compacted to the correct density. A poorly densified joint will also appear damp for a long period after the rest of the pavement dries.

As soon as the crack is 1/8 inch or larger in size, it should be thoroughly cleaned and filled with a sealant. If already wider than 1-1/2 inches, the joint should be cleaned sound material and a fine, dense-graded, high-asphalt-content hot mix used and compacted while the mix and joint are hot. Joints should be crowned, not just matched, and a good tack on the joint with emulsified asphalt will also help. There are many systems in use now. Exercise judgment to choose the best system for the type of pavement to be repaired.

When required, promptly paint these damp joints with a thin coat of liquid asphalt covered with sand. This rapidly reduces the number of times the joint opens up and seals water out of the pavement layer.

3. Delamination

Delamination occurs when a large section of pavement surface literally peels off the pavement below. While more common on portland cement concrete overlays where a tack coat was not used or the thickness was not sufficient, it can also occur on an asphalt overlay where the lack of tack coat is compounded by wheel ruts not being leveled before overlaying. Poor density results, water gets in between the overlay, and traffic works at it until stripping and raveling lead to eventual delamination. Delamination is usually identifiable by spots of damp pavement in wheel paths that take significantly longer periods of time to dry out. The extent of the weakness sometimes can be isolated by a hollow ringing sound when a solid aluminum rod is tapped on the pavement.

Repair is difficult with cold mixtures in these thin areas, and sometimes it is better to enlarge the section, bevel the edges and leave it alone until hot mix with good tack coat and sufficient compaction equipment can be used under dry conditions.

Most delamination involves thin layers, and the procedure above is generally safe. If the delaminated area is greater than 2 inches thick, place hot mix with good tack and the best compaction effort possible.

INTERSECTIONS

Many street intersections are major pothole generators, even though the streets leading to them are in excellent condition. They are, quite often, severely weakened by having numerous manhole castings, water main shutoff valves and other utility structures cutting up the overall continuity and strength of the pavement. This weakness shows up in overall performance.

Intersections also take a great deal of abuse in terms of the stopping, starting and turning movements of vehicles. These movements are quite stressful on the pavement structure, particularly with relatively thin pavements (say less than 4 inches). An additional problem with intersections is providing good positive drainage, since the slopes through the intersection very often have to be flattened in order to meet the intersecting roadways without causing noticeable bumps. As a result, water sometimes stays on the pavement longer than on other sections of the roadway.

At intersections with thicker pavements (over 4 inches thick) potholing by raveling may occur on the surface (top 1 inch) due to water and traffic scuffing at poor patches or utility casting edge. In this case, the top 1 inch of the surface of the intersection can be removed by milling machines or heated by infrared heaters and reworked (or overlaid) to a smooth finish that drains well and rides well.

MANHOLES AND OTHER UTILITY CASTINGS

Manholes and other castings contribute greatly to the development of potholes. While this is more prevalent on thinner pavements, it occurs on thick pavements also. There are two major contributing factors to this poor performance at manhole and utility castings. The first is that densification of the asphalt around the casting is difficult and is, very often, not given the attention it deserves. The other problem is a condition where the pavement is too thin at the casting.

What is needed is a better pavement detail at the casting. Since no specific research has been conducted that focuses on this problem, several suggestions are offered. First of all, in building pavements that are thin it is suggested that a transition area for a distance of about five feet in diameter around a manhole structure be used to thicken the pavement to at least 4 inches. Preferably it should be thickened to the full depth of the manhole casting or 8 inches. This area should be compacted with extra care to be sure that good densification occurs around

the manhole. If a relatively thick pavement is put in and not properly densified, post-construction compaction may leave an undesirable lip at the casting.

Another manhole casting detail used by many agencies is a portland cement concrete collar around the casting. This is generally placed from the base of the casting to within 1 or 2 inches of the top of the casing. The top 1 or 2 inches is then filled with hot asphalt mix as part of the finished pavement surface. The concrete collar arrangement has, in some cases, worked well and, in other cases, it too has performed poorly. The problem is that densifying 1 to 2 inches of hot mix on top of the concrete is most critical to the performance, as water can easily get into or through the thin 1- or 2-inch layer. As deicing chemicals permeate this layer and get to the concrete, portland cement concrete deterioration continually takes place. This condition leads to continuous raveling which is very difficult to patch permanently.

When asphalt-aggregate mixes are to be placed in lifts thicker than 3/4 inch, heavier asphalts should be used whenever possible. When used in thick lifts MC-250 is easily rutted and shoved by traffic. If a lift of asphalt will be over 2-1/2 inches thick, place it in two lifts. Compact the first lift to proper density before placing the second lift.

USES OF ASPHALT

OCCURRENCE

Asphalt is a natural constituent of most petroleums in which it exists in solution. The crude petroleum is refined to separate the various fractions and recover the asphalt. Similar processes occurring in nature have formed natural deposits of asphalt, some practically free from extraneous matter and some in which the asphalt has become mixed with variable quantities of mineral matter, water, and other substances. Natural deposits in which asphalt occurs within a porous rock structure are known as rock asphalts.

PROPERTIES

Asphalt is of particular interest to the engineer because it is a strong cement readily adhesive, highly waterproof, and durable. It is a plastic substance that imparts controllable flexibility to mixtures of mineral aggregates with which it is usually combined. It is, moreover, highly resistant to the action of most acids, alkalies, and salts. Although a solid or semi-solid at ordinary atmospheric temperatures, asphalt may be readily

liquefied by applying heat, or by dissolving it in petroleum solvents of varying volatility, or by emulsifying it.

BRIEF HISTORY

Prehistoric - Skeletons of prehistoric animals preserved intact to present day in surface deposits of asphalt, La Brea Pit, Los Angeles, California.

3200 to 540 B.C. - Recent archaeological excavations show extensive use of asphalt in Mesopotamia and Indus Valley, as cement for masonry and street construction and as waterproofing layer for temple baths and water tanks.

300 B.C. - Asphalt extensively used for mummification in Egypt.

A.D. 1802 - Rock asphalt used in France for floor, bridge, and sidewalk surfacing.

A.D. 1838 - Rock asphalt imported and used in sidewalk construction in Philadelphia.

A.D. 1870 (circa) - First asphalt pavement laid in Newark, New Jersey by Professor E.J. DeSmedt, a Belgian chemist.

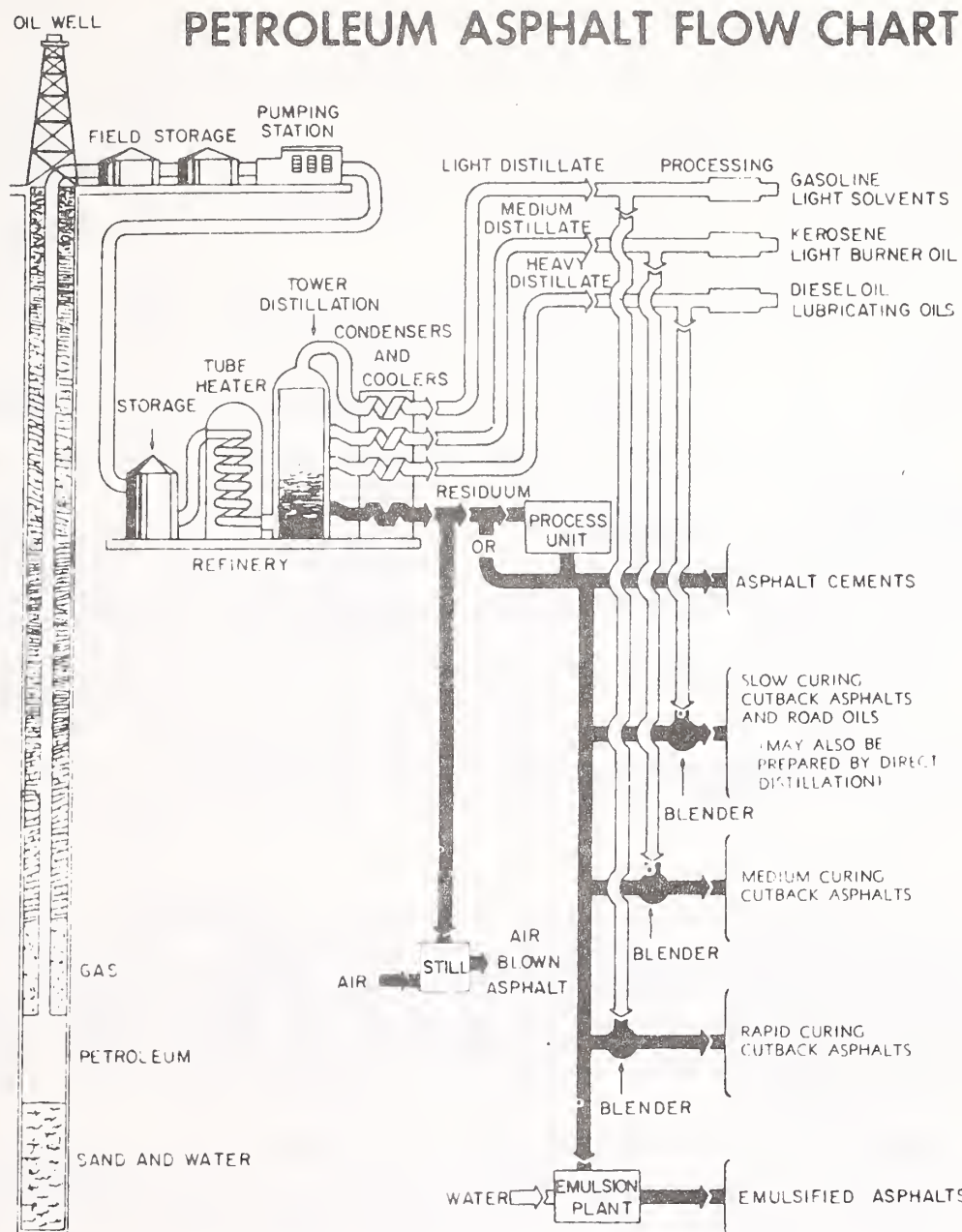
A.D. 1876 - First sheet asphalt pavement laid in Washington, D.C., with imported lake asphalt.

A.D. 1902 - Approximately 20,000 tons of asphalt refined from petroleum in the United States.

Since 1926 - The Petroleum asphalt and road oil tonnage produced annually has increased steadily - from 3,000,000 tons in 1926 to over 11,000,000 tons in 1950. Then to more than 34,000,000 tons in 1979.

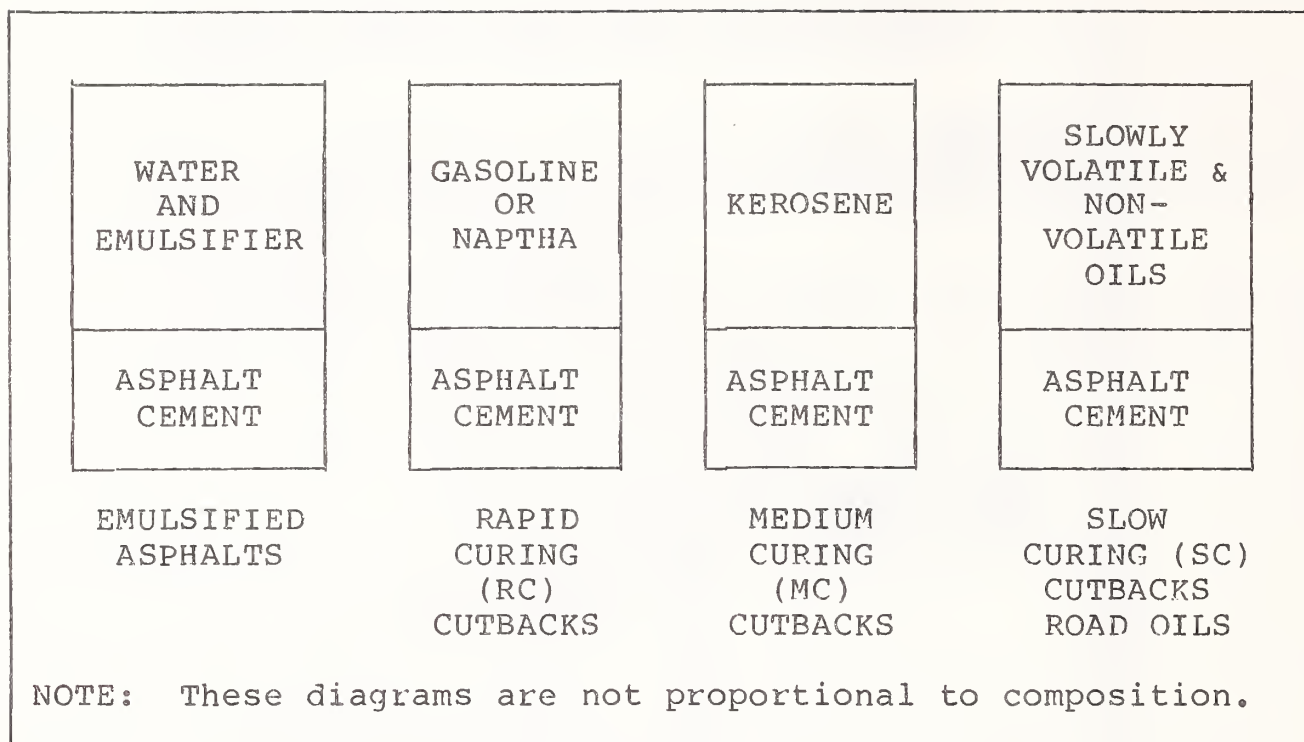
ASPHALT FROM PETROLEUM

Almost all asphalt used in the United States is refined from petroleum. Such asphalt is produced in a variety of types and grades ranging from hard brittle solids to almost water-thin liquids. The semisolid form, known as asphalt cement, is the basic material. Types of products produced by refining are shown in the chart on Page 13.



Petroleum asphalt flow chart

Some asphalt products are made fluid by emulsifying asphalt cements with water, or by cutting back or blending them with petroleum distillates. Types of emulsified or cutback products are illustrated by the following chart.



EMULSIFIED AND CUTBACK PRODUCTS

SCOPE

This is a how-to-do-it manual, limited to specific information on the use of asphalt in pavement maintenance. Planning, programming, financing and administration are beyond its scope. Other publications, one of which is Street and Urban Road Maintenance, published by the American Public Works Association, covers these phases quite well.

Pavement maintenance is a major activity of the highway department. Usually, money for maintenance is limited and the maintenance man is called upon to "make one dollar do the work of two." This is not easy.

Large differences in soil types, climate, terrain, traffic and other factors make for greatly varying problems, even within small areas. Some regions are rugged and mountainous while others are fairly smooth and level; some have heavy rainfall, others are semi-arid; some highways and streets must accommodate vehicles carrying coal ore, logs, or other heavy loads, while others are subjected to only lightweight traffic.

Yet, despite these differences, there are maintenance methods that can be used equally well in all regions. Presenting some of these methods is the purpose of this manual. Let's start by defining some terms.

1. ASPHALT

"A dark brown to black cementitious material in which the predominating constituents are bitumens which occur in nature or are obtained in petroleum processing." Asphalt is a constituent in varying proportions of most crude petroleum.

2. ASPHALT CEMENT

Asphalt that is refined to meet specifications for paving, industrial, and special purposes.

3. ASPHALT CONCRETE

High-quality, thoroughly controlled hot mixture of asphalt cement and well-graded, high-quality aggregate, thoroughly compacted into a uniform dense mass typified by Asphalt Institute Type IV mixes. (See Specifications and Construction Methods for Asphalt Concrete and Other Plant Mix Types, Specification Series No. 1 (SS-1), The Asphalt Institute.)

4. ASPHALT EMULSION SLURRY SEAL

A mixture of slow-setting emulsified asphalt, fine aggregate and mineral filler, with water added to produce slurry consistency.

5. ASPHALT FOG SEAL

A light application of slow-setting asphalt emulsion diluted with water. It is used to renew old asphalt surfaces and to seal small cracks and surface voids. The emulsion is diluted with an equal amount of water and sprayed at the rate of (0.45 to 0.9 litre/m²) 0.1 to 0.2 gal/yd² (of diluted material), depending on the texture and dryness of the old pavement.

6. ASPHALT JOINT FILLER

An asphalt produce used for filling cracks and joints in pavement and other structures.

7. ASPHALT JOINT FILLERS, PREFORMED

Premolded strips of asphalt mixed with fine mineral substances, fibrous materials, cork, sawdust, or similar materials; manufactured in dimensions suitable for construction joints.

8. ASPHALT LEVELING COURSE

A course (asphalt aggregate mixture) of variable thickness used to eliminate irregularities in the contour of an existing surface prior to superimposed treatment or construction.

9. ASPHALT, NATURAL (NATIVE)

Asphalt occurring in nature which has been derived from petroleum by natural processes of evaporation of volatile fractions leaving the asphalt fractions. The native asphalts of most importance are found in the Trinidad and Bermudez Lake deposits. Asphalt from these sources often is called LAKE ASPHALT.

10. ASPHALT OVERLAY

One or more courses of asphalt construction on an existing pavement. The overlay generally includes a leveling course, to correct the contour of the old pavement, followed by uniform course or courses to provided needed thickness. (Overlays usually are considered construction, not maintenance.)

11. ASPHALT PAVEMENTS

Pavements consisting of a surface course of mineral aggregate coated and cemented together with asphalt cement on supporting courses such as asphalt bases; crushed stone, slag, or gravel; or on portland cement concrete, brick, or block pavement.

12. ASPHALT PAVEMENT STRUCTURE

(Sometimes called Flexible Pavement Structure) - Courses of asphalt-aggregate mixtures, plus any non-rigid courses between the asphalt construction and the foundation or subgrade.

13. ASPHALT, PETROLEUM

Asphalt refined from crude petroleum.

14. ASPHALT PRIME COAT

An application of low-viscosity cutback asphalt to an absorbent surface. It is used to prepare an untreated base for an asphalt surface. The prime penetrates into the base and plugs the voids, hardens the top and helps bind it to the

overlying asphalt course. It also reduces the necessity of maintaining an untreated base course prior to placing the asphalt pavement.

15. ASPHALT, ROCK

Porous rock such as sandstone or limestone that has become impregnated with natural asphalt through geologic process.

16. ASPHALT SEAL COAT

A thin asphalt surface treatment used to waterproof and improve the texture of an asphalt wearing surface. Depending on the purpose, seal coats may or may not be covered with aggregate. The main types of seal coats are aggregate seals, fog seals, emulsion slurry seals, and sand seals.

17. ASPHALT SURFACE TREATMENTS

Applications of asphaltic materials to any type of road or pavement surface, with or without a cover of mineral aggregate, which produce an increase in thickness of less than 2.5 centimeters (one inch).

18. ASPHALT TACK COAT

A very light application of asphalt applied to an existing asphalt or portland cement concrete surface. Asphalt emulsion diluted with water is the preferred type. It is used to ensure a bond between the surface being paved and the overlying course.

19. BITUMEN

A mixture of hydrocarbons of natural or pyrogenous origin, or a combination of both; frequently accompanied by nonmetallic derivatives which may be gaseous; liquid, semisolid, or solid; and which are completely soluble in carbon disulfide.

20. CUTBACK ASPHALT

Asphalt cement which has been liquefied by blending with petroleum solvents (also called diluents), as for the RC and MC cutback asphalts (see a and b below). Upon exposure to atmospheric conditions the diluents evaporate, leaving the asphalt cement to perform its function.

a. Rapid-Curing (RC) Asphalt

Cutback asphalt composed of asphalt cement and a naptha or gasoline-type diluent of high volatility.

b. Medium-Curing (MC) Asphalt

Cutback asphalt composed of asphalt cement and a kerosene-type diluent of medium volatility.

c. Slow-Curing (SC) Asphalt

Cutback asphalt composed of asphalt cement and oils of low volatility.

d. Road-Oil

A heavy petroleum oil, usually one of the Slow-Curing (SC) grades.

21. DEEP-STRENGTH ASPHALT PAVEMENT

DEEP-STRENGTH® is a term registered by The Asphalt Institute with the U.S. Patent Office. The term DEEP-STRENGTH (also called "mark") certifies that the pavement is constructed of asphalt with an asphalt surface on an asphalt base and in accordance with design concepts established by The Asphalt Institute. (See Thickness Design Manual (MS-1)).

22. DEFLECTION

The amount of downward vertical movement of a surface due to the application of a load to the surface.

23. EMULSIFIED ASPHALT

An emulsion of asphalt cement and water that contains a small amount of an emulsifying agent, a heterogeneous system containing two normally immiscible phases (asphalt and water) in which the water forms the continuous phase of the emulsion, and minute globules of asphalt form the discontinuous phase. Emulsified asphalts may be of either the anionic, electronegatively charged asphalt globules, or cationic, electropositively charged asphalt globule types, depending upon the emulsifying agent.

24. FLUX OR FLUX OIL

A thick, relatively nonvolatile fraction of petroleum which may be used to soften asphalt to a desired consistency; often used as base stock for manufacture of roofing asphalts.

25. FULL-DEPTH ASPHALT PAVEMENT

An asphalt pavement structure in which asphalt mixtures are employed for all courses above the sub-grade or improved

subgrade. A Full-Depth asphalt pavement is laid directly on the prepared subgrade.

26. GILSONITE

A form of natural asphalt, hard and brittle, occurring in rock crevices or veins from which it is mined.

27. MIXED-IN-PLACE (ROAD MIX)

An asphalt course produced by mixing mineral aggregate and cutback or emulsified asphalt at the road site by means of travel plants, motor graders, drags, or special road-mixing equipment.

28. PAVEMENT - see PAVEMENT STRUCTURE

(As used in this manual, the word "pavement" means "pavement structure.")

29. PAVEMENT STRUCTURE

All courses of selected material placed on the foundation or subgrade soil, other than any layers of courses constructed in grading operations.

30. PLANT MIX

A mixture, produced in an asphalt mixing plant, which consists of mineral aggregate uniformly coated with asphalt.

31. PLANT-MIXED SURFACE TREATMENTS .

A layer, less than (2.5 cm.) 1 in. thick, of aggregate that is coated with asphalt in a plant. Plant-mixed surface treatments are used extensively for providing skid-resistant surfaces.

32. THICK-LIFT ASPHALT PAVEMENT

An asphalt pavement structure in which the asphalt base course is placed in one or more lifts of (10 or more centimeters) 4 or more inches compacted thickness.

33. UNDERSEALING ASPHALT

A high softening point asphalt used to fill cavities beneath portland cement concrete slabs and occasionally to correct the vertical alignment by raising individual slabs.

MAINTENANCE DEFINED

Pavement maintenance is not easy to define. Highway departments agree in general as to what it is but there are some minor differences, chiefly in scope. Some call pavement improvement "maintenance." Others include only the work which keeps the pavement in its as-constructed condition. There also is some disagreement as to whether repairs made necessary by unusual events such as earthquakes, landslides, forest fires, windstorms, or severe traffic accidents should properly be classified as maintenance.

Taking all of these into consideration, the definition which seems to most nearly fit is:

Pavement maintenance is the routine work performed to keep a pavement, under normal conditions of traffic and normal forces of nature, as nearly as possible in its as-constructed condition.

WHY MAINTENANCE IS NECESSARY

All pavements require maintenance, the chief reason being that stresses producing minor defects are constantly working in all pavements. Such stresses may be caused by change in temperature or moisture content, by traffic, or by small movements in the underlying or adjacent earth. Cracks, holes, depressions, and other types of distress are the visible evidence of pavement wear. They are simply the end results of the process of wear which begins when construction ends. In urban areas, ditches dug through the pavement for water lines and other utilities are a major cause of pavement maintenance.

PREVENTIVE MAINTENANCE

"A Stitch in Time..." The early detection and repair of minor defects is, without doubt, the most important work done by the maintenance crew. Cracks and other surface breaks, which in their first stages are almost unnoticeable, may develop into serious defects if not soon repaired. This may occur in a very few days on an underdesigned pavement under heavy traffic. For this reason, frequent close inspections of the pavement should be made by qualified employees. Indeed, this measure is necessary toward the best use of maintenance money.

An inspection made from a moving vehicle, even one which creeps, is usually not close enough to detect areas where distress may begin. Often the cracks or other surface defects are so small that only a person on foot can spot them. There are other small signs, such as mud or water on the pavement or shoulder, which to

an experienced observer may signal future trouble. It is best, then, to walk the pavement for close inspection; or, when there are not enough men available for this purpose, to spot check selected stretches of roadway.

Upon detection of the warning signs, a detailed investigation, including trenching across the failed area if necessary, should be made to determine the kind of repair called for. If the pavement seems to be moving under traffic, deflection measurements should be carried out to determine the extent of the affected area.

All persons making pavement inspections on foot should take proper safety precautions. They should wear easily-seen clothes. They should be protected by adequate warning signs and devices, or followed by a car or truck displaying warning devices. Safety flags, vests, and approved hard hats are required.

DRAINAGE MAINTENANCE

A form of preventive maintenance is seasonal inspection and cleaning of drainage systems. If drains are kept working properly some of the major causes of pavement damage are eliminated. Each inspection should include all surface drainage structures, ditches and channels to insure that they are working as designed. If any part of the system is clogged, it should be cleaned out immediately.

At least twice a year subsurface drains should be examined to make sure they are working as intended. The abnormal appearance of water on the pavement surface may indicate that subsurface drains are improperly located, incorrectly designed, or clogged.

All drain outlets should be well marked on the ground and on maintenance maps. If this is done, they will not be overlooked on inspection trips.

Detailed information about pavement drainage is contained in Drainage of Asphalt Pavement Structures, Manual Series No. 15 (MS-15), The Asphalt Institute. Most of the information in this manual applies equally to portland cement concrete pavements.

MAKE REPAIRS PROMPTLY

Repairs should be made as quickly as possible after the need for them is discovered. This is particularly important when the defect makes driving hazardous.

Often, weather conditions make temporary repairs necessary to prevent further damage until more permanent repairs can be made.

As examples, crack filling is most likely to be successful during periods of cool, dry weather; chuck (pot) hole patches adhere best when the pavement is warm and dry; and seal coats, or other surface treatments require warm and dry weather for best results. Selecting the best time to make repairs, therefore, involves the careful balancing of several things and requires both experience and judgment.

PREVENTION OF DEFECT RECURRENCE

In all cases of pavement distress it is best to determine first the cause or causes of the difficulty. Then repairs can be made which will not only correct the damage but will also prevent or retard its happening again. Time and money spent for such repairs are well spent because the same repairs will not have to be made over and over.

STREET MAINTENANCE

Street and urban roads can develop all of the defects discussed later. However, some of these defects are much more of a problem in streets than in any other class of pavement structure. Shoving and corrugating of asphalt pavement surfaces, for example, show up more often in urban areas. Limited speeds on steep grades and frequent traffic lights and stop signs at intersections multiply the need for braking and the result is shoving or corrugating of low stability pavement surfaces. A heater-planer has been used successfully in repairing these defects (see Corrugations and Shoving).

A problem almost exclusive to urban areas is that of utility cuts in the pavement. In most cases these cuts are made by or for utility companies. And, although repairs are controlled by municipal regulations, all too often the backfilled trenches settle, requiring maintenance by the department. Settlement can be minimized by selecting a well-graded granular backfill and compacting it, at the proper moisture content, with tampers or vibrating compactors. Compacting trench backfill by flooding or puddling with water is not a good procedure. For this to work at all, the in-place material surrounding the excavation must be more porous than the backfill material. And the backfill material must be granular and quite porous itself.

Utility Cuts, describes a procedure for repairing these settled patches in asphalt pavements. The same procedure is used for portland cement concrete pavements. When Full-Depth asphalt concrete is used for the repair the patch can be completed and opened quickly to traffic. Sometimes winter conditions or other considerations make temporary repairs necessary. But there are many utility cuts that can be permanently repaired the first time.

Often, in growing urban areas, streets become scarred from many cuts and patches for utility connections; or they are weathered and need sealing; or they become slippery from polished aggregate or bleeding asphalt. Many cities have found that a thin hot-mix overlay or a surface treatment is the most economical and effective treatment for these conditions.

Traffic control usually is more of a problem in urban areas than in rural areas. Street maintenance, then, must be done as quickly and as efficiently as possible with the least interference to, and from, traffic. Each city has its own special problems connected with traffic control at solve them by its own method. The common goals of all, however, are to minimize disruption of traffic flow while providing maximum safety for the public and the maintenance crew.

THE IMPORTANCE OF SKILLED MAINTENANCE PERSONNEL

Maintenance work requires proper supervision, skilled workmen, and good workmanship. Unless all three are employed, it is likely that some repair work will be poorly done and may have to be repeated. Since most pavement repairs involve the use of asphalt, a thorough knowledge of this material is essential for maintenance men. This is especially true for supervisors and inspectors. Successful pavement maintenance requires a knowledge of which asphalts are available and how to use them (see Chapter IV). Although the basic skills needed for pavement maintenance can be acquired only through experience gained in the actual work, a close study of the literature published by The Asphalt Institute will be found most useful. (See Appendix C)

THE IMPORTANCE OF WEATHER

Preferably, patching or resurfacing work should be done during warm, (10°C) 50°F and above, and dry weather. When hot or warm mixtures are placed on cold pavements, they may cool so fast that adequate compaction is difficult. This cooling effect is emphasized if the mixture is placed in thin layers. Moreover, asphalt and asphalt mixtures usually do not bond well to damp surfaces.

This does not mean that repairs cannot be made during cold or damp weather. Rather, they require much greater care when made during such periods. They also have much less chance of being satisfactory. It is better, however, when the safety and comfort of the traveling public are concerned, to make the repairs even though they may be only temporary. Also, a delay in repairs may allow small surface breaks to progress into major failures.

Mixtures containing cutback or emulsified asphalt are slow in curing out when the humidity is high. This is because the air,

which already contains a large amount of water vapor, does not readily allow solvent evaporation. Low temperatures also slow up solvent evaporation.

Seal coats and other surface treatments can be affected by moisture during the first few hours after their placement. Rain and/or fast traffic during this critical period will often result in the loss of most of the cover aggregate.

A phone call to the weather bureau may help in scheduling maintenance work during uncertain weather.

SAFETY

An important contribution to high-quality maintenance is an active safety program. For the maintenance employee, safety measures reduce fear of injury, allowing greater freedom of mind in performing his task. This results in doing a better job.

For the safety of the workers, the motorist must be warned about what is going on ahead and what they must do as they pass through the work area. Signs and warning devices should be placed far enough ahead for him to grasp their meaning. Yet they should not be so far ahead that they lose their meaning. A sign indicating the end of the work area also is desirable. The use of a flag-person near the work is necessary when sight distance is restricted or dangerous driving conditions exist.

The kind of safety equipment to be used by the maintenance employee depends upon the type of work they are doing. Examples: If they are subsealing a portland cement concrete slab they should wear clothing and safety gear that leave no skin exposed, obviating injury in the event of hot asphalt blowing back from the hole. If they are merely sweeping a dirty pavement with a power broom, a dust mask and goggles may be all the extra equipment necessary. As appropriate, members of the maintenance crew should be furnished with hard hats, goggles, asbestos gloves, and any other safety apparel that will reduce the possibility of accidents.

MAINTENANCE OF ASPHALT PAVEMENTS

TYPES OF ASPHALT PAVEMENT

Asphalt pavement maintenance as discussed in this manual applies to all asphalt pavement structures from Full-Depth asphalt to surface treatments (see Definitions). It applies to the traveled

way and shoulders of roads, streets; to parking lots and aprons; and to other areas such as driveways. Asphalt overlays on portland cement concrete, brick, or other materials are also included.

This portion covers the most common types of defects and failures in asphalt pavements, their usual causes, and suggested methods of repair. This does not imply, however, that the subject is completely covered. There may be unusual defects that do not fall into any of the following categories. There also are many good methods of repair that are not described here.

MOISTURE AND GRANULAR BASES

At the present time many asphalt pavements consist of an asphalt surface over a granular base. The base materials range from gravel and pit-run products to crushed and processed rock. These bases serve well as long as they are properly drained. But if they become saturated with water they lost strength rapidly under the weight and action of traffic.

Saturation of granular bases is the cause of many maintenance problems. Among them are asphalt-surfaced pavements on granular bases that become soft and crack in the familiar alligator or chicken-wire pattern. These are problems that won't go away by filling cracks or placing skin patches. The cause of the distress should be eliminated.

Some high-type pavements with granular bases are designed with drainage systems to prevent saturation by ground or surface water. But there are many thousands of miles of sand-clay-gravel roads, now surfaced with asphalt, that become saturated and give trouble. Usually these roads have a high percentage of plastic fine material in them as binder, needed to hold the materials in place when the surface was open. As sand-clay-gravel roads they became saturated when it rained but dried out rapidly because moisture was free to evaporate. With the addition of the impervious asphalt pavement, this evaporation through the surface is blocked. The result is that water migrating into the base materials from the shoulders and from the subgrade below cannot escape and the sand-clay-gravel loses strength as it becomes soaked. Cracking, heaving, and other forms of distress take place. Also, in its weakened condition the base, unable to support the traffic, deflects more than normal and cracking is intensified.

Therefore, when investigating surface failures which appear to be related to excessive deflection, the base should be checked for plastic fines or trapped water. If so, repair may call for

digging out the broken area to sound material, improving drainage, and patching with asphalt patching mixture.

BENKELMAN BEAM

The extent of areas of excessive deflection can be determined quite easily with a device called the Benkelman Beam. This device has a narrow beam that is slipped between the dual tires of the rear axle of a loaded truck. A foot on the end of the beam rests on the pavement between the tires. The truck moves ahead at creep speed and the total pavement rebound deflection is ready by means of a dial gauge. (Rebound deflection is the amount of vertical rebound of a surface that occurs when a load is removed from the surface.)

Rebound deflection readings should be taken at locations sufficient to outline the whole area of excessive deflection before repairs are made. Areas of excessive deflection may be estimated by comparing deflection in the distressed area with the average deflection in areas that are performing well.

PATCHING MIXTURES

Many patches bleed, become unstable, and are subject to pushing after placement. The cause usually is an excess of asphalt in the patching mixture. Patch instability can also be caused by not allowing the patch (when made with a stockpiled patching mixture) to cure before subjecting it to traffic.

For the best patching mixture a laboratory investigation should be made of the materials proposed for use.

High-quality hot-mixed patching mixtures, although costing more than other patching materials, result in longer-lasting patches. The major cost of patching lies in placing the patch not in the cost of the material. Therefore, the use of hot-mix materials for patches outlasting many times those made with other materials is a readily-apparent economy.

It is usually possible to get a hot asphalt mixture for patching, even in out-of-the-way areas. One method employs a mix-heater to heat stockpiled pre-mix prior to making the patch. There are several types of these heaters. One type can be suspended from the tailgate of the truck carrying the pre-mix. Another is trailer mounted.

Also available is a small portable mix-plant designed for small jobs and maintenance operations. It is equipped with a small dryer and pugmill. Asphalt is stored in a tank on the mix-plant

trailer. Aggregate usually is carried in a truck towing the plant. Output at jobsite is 4.5-9 tonnes (5-10 tons) per hour of hot-mix material.

PRIME AND TACK COATS

If the base of a deep patch is made with untreated material it should be primed with 0.9 to 1.4 litre/m² (0.20 to 0.30 gal/yd²) of cutback asphalt. If spray equipment is not available, hand methods can be used to apply the prime. But care must be taken not to apply an excess of asphalt. The amount of asphalt material used to prime the base should be only enough to knit together the top particles.

The prepared edges of the surfaces surrounding the area being patched should be tack coated to ensure a bond between them and the patch material.

If the prime and tack coat are of asphalt emulsion, enough time should be allowed for the emulsion to "break" and most of the water to dry out before the patch-mix is placed. Similarly, a rapid curing or medium-curing asphalt should be given time to penetrate and cure before the patch mix is placed.

For a surface patch, a light tack coat is necessary. A slip plane may develop from either the absence of a tack coat or too heavy a tack coat. Application methods are similar to those used for a prime coat except that the quantities used are much smaller.

PLACING PATCHING MIXTURES

After the area to be patched has been properly prepared, including trimming of edges and applying the correct prime coat or tack coat, there remains only the placing and compacting of the mix.

Segregation should be prevented. Patching mixture should never be dumped from the truck into the patch area. It should be shoveled directly from the truck or from a board on to which it has been dumped. The shovels-full of mix should be placed against the edges first rather than piled in the center and raked to the edges.

It should never be necessary to pull material from the center of the patch to the edge in making the joint. If more material is needed at the edge it should be deposited there and the excess raked away. The quantity of material placed in the patch area should be sufficient to ensure that, after compaction, the patch surface will not be below that of the adjacent pavement. However, if too much material is placed in the patch area a hump

will result. A stringline and/or a straightedge, used properly, can be a great help in producing a smooth riding surface.

COMPACTING PATCHING MIXTURES

In compacting the patch, the first pass and return of the roller, vibratory compactor, or maintenance truck wheels (although not recommended) should overlap not more than 15 cm (6 in.) on to the patch material at one edge. This should then be repeated on the opposite side to compact the material into the edge joints. Compaction should then proceed from the low side to the high side, with each pass and return lapping an additional few inches on to the patch. When proper equipment and procedures are used the surface of the patch should be at the same grade as the surrounding pavement. If hand tamping or other light compaction methods are used, however, the surface of the completed patch should be slightly higher than the pavement. Traffic will compress the patch further.

CRACKING

GENERAL

Cracking takes many forms. Simple crack filling may be the right treatment in some cases. In others, complete removal of the affected area and the installation of drainage may be necessary before effective repairs can be carried out. To make proper repairs, then, the necessary first step is to determine the cause of cracking.

The repair techniques for the correction of various forms of cracking discussed in this section are not necessarily the only correct ways to do the job. But they are proven ways that should result in neat, long-lasting repairs.

ALLIGATOR CRACKS

These are interconnected cracks forming a series of small blocks resembling an alligator's skin or chicken-wire.

1. CAUSE

In most cases, alligator cracking is caused by excessive deflection of the surface over unstable subgrade or lower courses of the pavement. The unstable support usually is the result of saturated granular bases or subgrade. The affected areas in most cases are not large. Sometimes, however, they will cover entire sections of a pavement. When this happens, it probably is due to repeated loads that exceed the load-carrying capacity of the pavement.

2. REPAIR

Since alligator cracking usually is the result of saturated bases or subgrades, correction should include removing the wet material and installing needed drainage. Asphalt plant-mixed material can then be used for the full depth of a strong patch. (This may be the least expensive repair because of the single operation with one material.) If the asphalt plant-mixed material is not available, new granular base material in layers not exceeding (15 cm.) 6 in. each are compacted in. The granular base should then be primed and patched.

When necessary, temporary repairs can be made by applying skin patches or aggregate seal coats to the affected areas. In any event, repairs should be made promptly to avoid further damage to the pavement.

In the case of cracking from overloading, a properly designed overlay will correct the condition. Refer to Asphalt Overlays and Pavement Rehabilitation, Manual Series No. 17 (MS-17), The Asphalt Institute.

DEEP PATCH (PERMANENT REPAIR)

- (a) Remove the surface and base as deep as necessary to reach firm support, extending at least a foot into good pavement outside the cracked area. This may mean that some of the subgrade will also have to be removed. Make the cut square or rectangular with faces straight and vertical. One pair of faces should be at right angles to the direction of traffic. A pavement saw makes a fast and neat cut. Figure 1.

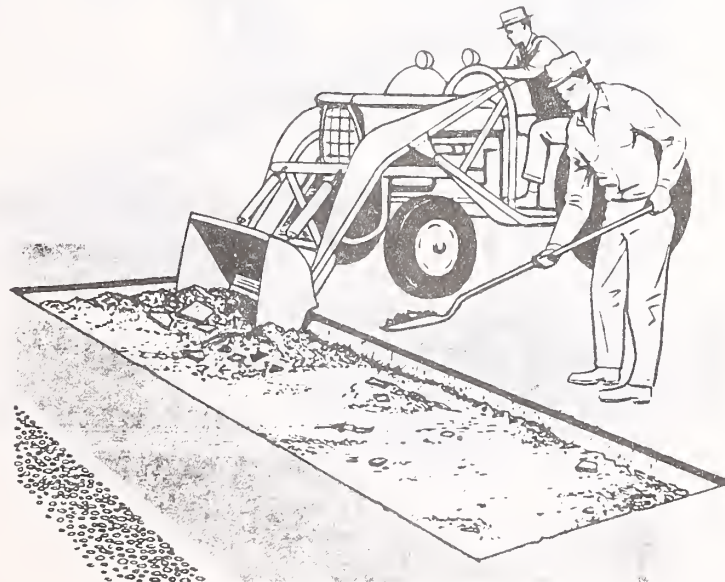


Figure 1.

- (b) If water is a cause of the failure, install drainage.
- (c) Apply a tack coat to the vertical faces. Figure 2.

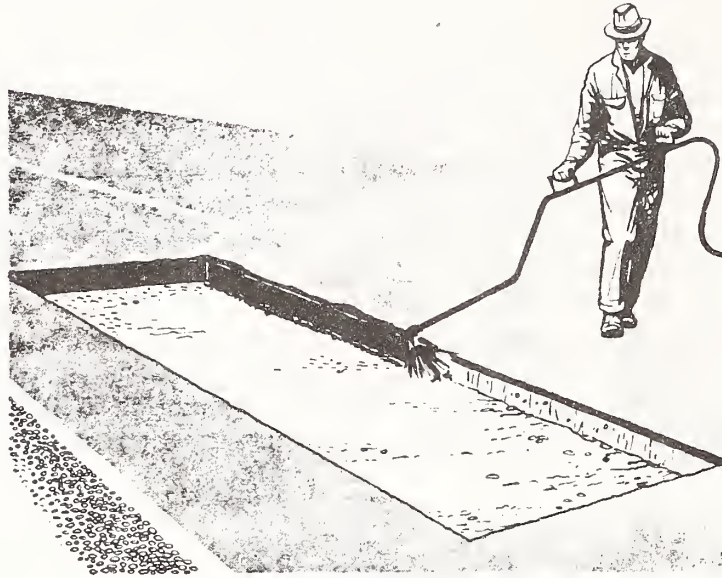


Figure 2.

- (d) For best results, backfill the hole with a dense-graded hot asphalt plant-mix. Figures 3 and 4. Spread carefully to prevent segregation of the mixture.



Figure 3. Backfilling hole with plant-mix



Figure 4. Spreading the mix.

If the asphalt mixture is not available, make the back-fill with a good granular base material. Part of the surface and upper base material removed from the hole, broken into small pieces and mixed thoroughly, can be placed in the bottom of the hole.

- (e) Compact in equal layers if the hole is more than (6.5 cm.) 2-1/2 inches deep. Compact each layer thoroughly. Compaction should be done with equipment most suited for the size of the job. A vibratory plate compactor is excellent for small patches. A roller may be more practical for large areas. Figure 5.

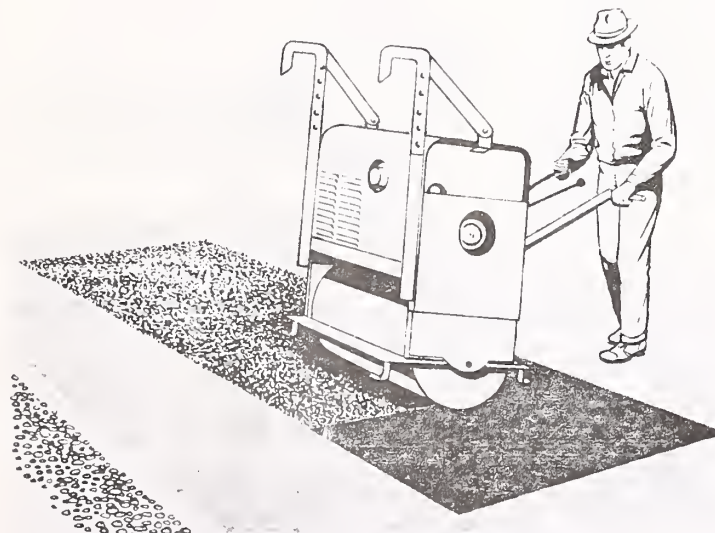


Figure 5. Compacting the mix.

- (f) Full-Depth asphalt mix placed directly on the subgrade needs no prime.
- (g) If granular base is used it should be primed. The repair is then completed by placing hot plant-mixed asphalt surfacing material, and compacting to the same grade as the surrounding pavement. If hot-mixed surfacing is not available, plant-mixed material using liquid asphalt can be used.
- (h) Use a straightedge or a stringline to check the riding quality and the alignment of the patch. Figure 6.

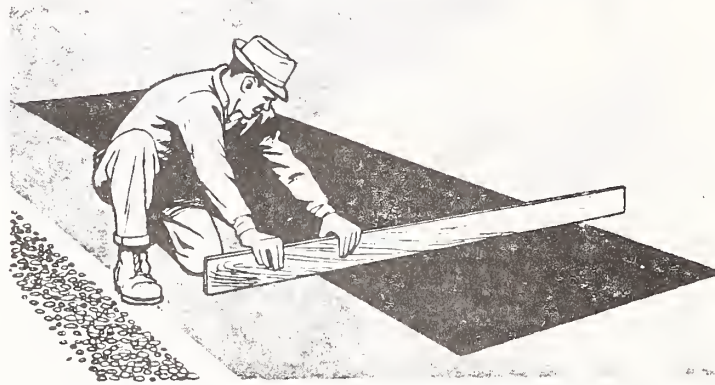
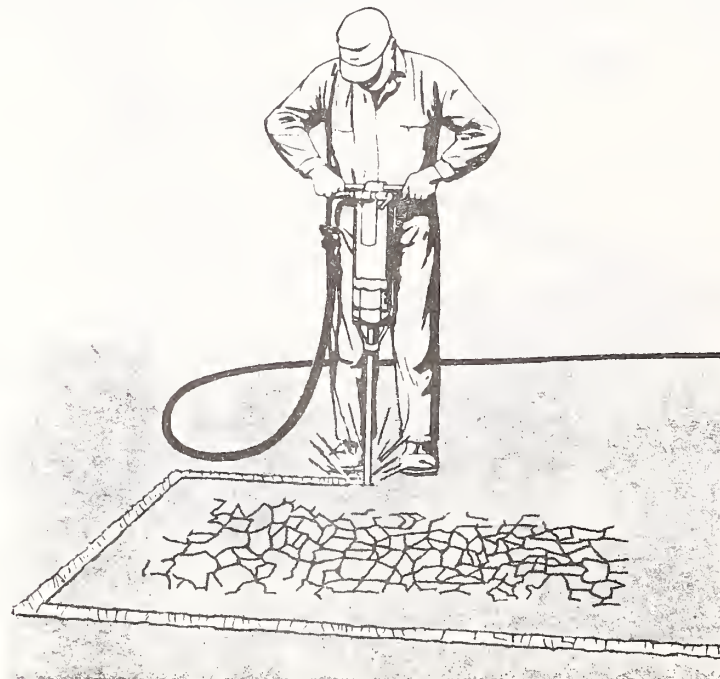


Figure 6. Straightedging the patch.

SKIN PATCH (TEMPORARY REPAIR) FOR AREAS WITH
CRACKS WIDER THAN (3 MILLIMETERS) 1/8 INCH

- (a) Cut a shallow trench around the area to be patched to provide a vertical face around the edge. Figure 7.



- (b) Clean the cracked area with brooms and, if necessary, compressed air.
- (c) Broom plant-mixed fine-graded asphalt material into cracks. Figure 8.



Figure 8. Brooming plant-mix into alligator cracks.

- (d) Compact with a vibratory plate compactor or roller. Figure 9.

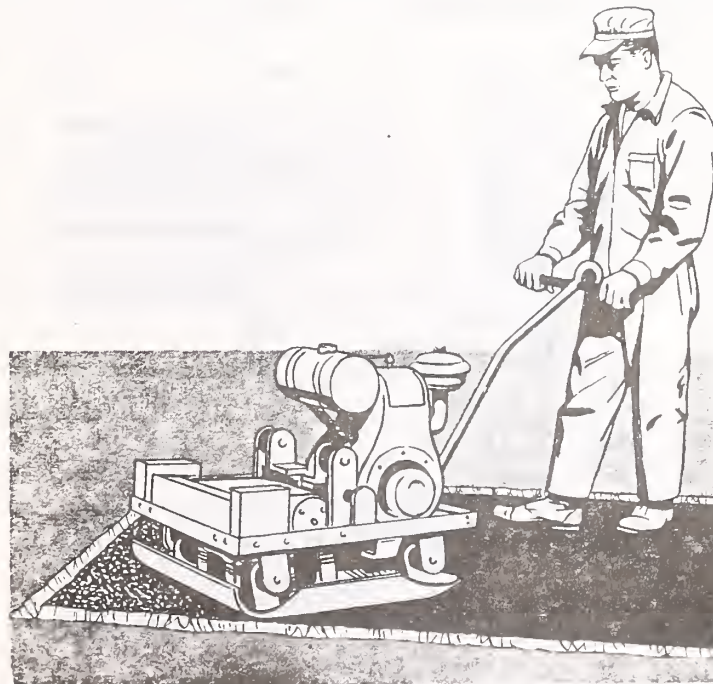


Figure 9. Compacting with vibratory plate compactor.

(e) Apply a tack coat. Figure 10.



Figure 10. Applying tack coat.

(f) Place a skin patch with hot plant-mixed asphalt material. If this material is not available, use plant mix with cutback or emulsified asphalt. Feather the edges carefully, removing coarse particles with lute and rake before compaction. Figure 11.



Figure 11. Placing skin patch of hot plant-mix.

- (g) Compact the patch with a vibratory plate compactor or roller. If neither is available, rolling may be done with the wheels of the truck that carries the mix. Figure 12.

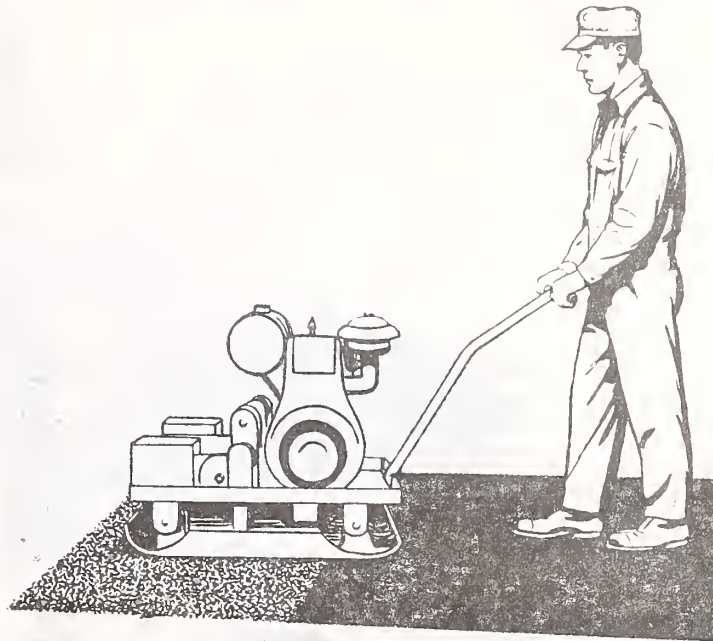


Figure 12. Compacting with vibratory plate compactor.

AGGREGATE SEAL COAT PATCH (TEMPORARY REPAIR)
FOR AREAS WITH CRACKS NARROWER THAN (3 MILLIMETERS) 1/8 INCH

- (a) Clean the cracked area with brooms and, if necessary, compressed air.
- (b) Spray the necessary amount of asphalt (either emulsion, rapid curing cutback, or medium curing cutback) on to the cleaned area. Usually, (0.7 or 1.1 litre/m²) 0.15 or 0.25 gal/yd² is enough for the seal coat, but, if an excessive amount is lost in the cracks, slightly more asphalt should be applied. Figure 13.



Figure 13. Spraying asphalt on alligator cracks.

- (c) Apply the cover aggregate immediately after spraying the asphalt. A good aggregate size for this type of patch is (6mm) 1.4 in. to No. 10 screenings. Figure 14.



Figure 14. Applying cover aggregate.

- (d) Roll the seal coat with rubber-tired equipment. If a roller is not available the wheels of the truck carrying the cover aggregate can be used. Figure 15.

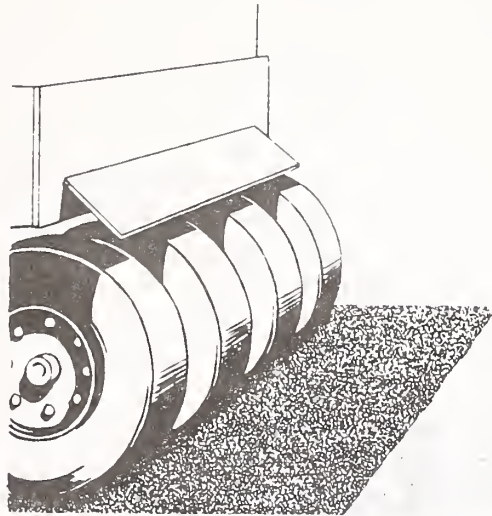


Figure 15. Rolling seal coat with rubber-tired equipment.

- (e) If it is necessary to build up the patched area to the level of the surrounding pavement, a second seal coat can be applied.
- (f) Allow to cure thoroughly before opening to traffic.

SLURRY SEAL PATCH (TEMPORARY REPAIR) FOR AREAS CRACKED FROM OVERLOADING

- (a) Clean the cracked area with brooms and, if necessary, compressed air.
- (b) Apply an asphalt emulsion slurry seal.

EDGE CRACKS

These are longitudinal cracks a third of a meter (one foot) or so from the edge of the pavement with or without transverse cracks branching towards the shoulder.

1. CAUSE

Usually, edge cracks are due to lack of lateral (shoulder) support. They may also be caused by settlement or yielding

of the material underlying the cracked area; which in turn may be the result of poor drainage, frost heave, or shrinkage from drying out of the surrounding earth. In the last case trees, bushes or other heavy vegetation close to the pavement edge may be a cause.

2. REPAIR

For temporary repair, fill as for reflection cracks. For more permanent repair, fill cracks with asphalt emulsion slurry or emulsified or cutback asphalt mixed with sand. If the edge of the pavement has settled bring up to grade with hot plant mix patching material.

- (a) Improve drainage. Install underdrains, if necessary.
- (b) Clean pavement and cracks with broom and compressed air.
- (c) Fill cracks with emulsion slurry or emulsified asphalt (SS-1, SS-1h, or CMS-2) mixed with sand. Wipe with a rubber-edged squeegee.
- (d) Apply a tack coat.
- (e) Bring settled edge up to grade by spreading hot asphalt plant-mixed material. Check the smoothness with a straightedge or a stringline. Compact with a vibrating plate compactor or a roller. Be sure that the edges of the patch are straight and neat.
- (f) Remove trees, shrubs, and other vegetation except grass from close to the pavement edge.

EDGE JOINT CRACKS

An edge joint crack is really a seam. It is the separation of the joint between the pavement and the shoulder. It is treated as a crack, however.

1. CAUSE

A common cause of "cracking" in a pavement-shoulder joint is alternate wetting and drying beneath the shoulder surface. This may result from poor drainage due to a shoulder higher than the main pavement, from a ridge of grass or joint-filling material, or from depressions in the pavement edge, all of which trap water and allow it to stand along and seep through the joint. Other causes are shoulder settlement, mix shrinkage, and trucks straddling the joint.

2. REPAIR

If water is the cause, the first step is to improve the drainage by getting rid of the condition that traps water. Then repair the crack, see Reflection Cracks.

LANE JOINT CRACKS

Lane joint cracks are longitudinal separations along the seam between two paving lanes.

1. CAUSE

This type of crack usually is caused by a weak seam between adjoining spreads in the courses of the pavement.

2. REPAIR

See Reflection Cracks.

REFLECTION CRACKS

These are cracks in asphalt overlays which reflect the crack pattern in the pavement structure underneath. The pattern may be longitudinal, transverse, diagonal, or block. They occur most frequently in asphalt overlays on portland cement concrete and on cement-treated bases. They may also occur in asphalt overlays on asphalt pavements whenever cracks in the old pavement have not been properly repaired.

1. CAUSE

Reflection cracks are caused by vertical or horizontal movements in the pavement beneath the overlay, brought on by expansion and contraction with temperature or moisture changes. They may be caused also by traffic or earth movements and by loss of moisture in subgrades with high clay contents.

2. REPAIR

Small cracks [less than (3 mm) 1/8 in. in width] are too small to seal effectively. Large cracks [(3 mm) 1/8 in. and over in width] are to be filled with asphalt emulsion slurry or light grade of emulsified asphalt mixed with fine sand. Also, special asphalt compounds or heavier bodied asphalt material may be used to fill large cracks.

The procedures described in this section are proven effective methods that can be used satisfactorily with confidence. The Maintenance and Equipment Division has more advanced equipment that makes these jobs easier, but the availability of this equipment is limited. Deferred maintenance is not maintenance at all. Use the newer equipment if it is available, but don't let a situation get out of control while you wait for the easy way.

- (a) Clean out crack with stiff-bristled broom and compressed air. Figure 16.



Figure 16. Cleaning out crack with broom and air.

- (b) Large crack. Using a hand squeegee and a broom, fill (do not overfill) with emulsion slurry or emulsified asphalt (SS-1, SS-1h, or CMS-2) mixed with sand. When cured, seal with emulsified asphalt using a pouring pot and a hand squeegee. Figure 17.



Figure 17. Sealing with pouring pot and hand squeegee.

- (c) Sprinkle surface of crack filler with dry sand to prevent pick-up by traffic. Figure 18.



Figure 18. Sprinkling surface with dry sand.

SHRINKAGE CRACKS

Shrinkage cracks are interconnected cracks forming a series of large blocks, usually with sharp corners or angles.

1. CAUSE

Often it is difficult to determine whether shrinkage cracks are caused by volume change in the asphalt mix or in the base or subgrade. Frequently, they are caused by volume change of fine aggregate asphalt mixes that have a high content of low penetration asphalt. Lack of traffic hastens shrinkage cracking in these pavements.

2. REPAIR

Fill cracks with asphalt emulsion slurry followed by a surface treatment or a slurry seal over the entire surface. (Refer to The Asphalt Institute's Specification SS-1 or Specification SS-2.)

- (a) Remove all loose matter from the cracks and pavement surface with brooms and compressed air.
- (b) Wet with water the surface of the pavement and all crack faces.
- (c) When all surfaces are uniformly damp, with no free water, apply a tack coat of asphalt emulsion diluted with equal parts of water.
- (d) Prepare the asphalt emulsion slurry mixture.
- (e) Pour slurry mixture into cracks and level with a hand squeegee. (If cracks are numerous slurry-seal the whole surface.)
- (f) When the slurry is cured until firm, surface-treat or slurry-seal the whole surface with equipment designed for the operation.)
- (g) Allow to cure until firm enough to prevent pick-up by traffic.

SLIPPAGE CRACKS

These are sometimes crescent-shaped cracks that point in the direction of the thrust of wheels on the pavement surface. This does not mean that they invariably point in the direction that traffic is going. For example, if brakes are applied on a vehicle going down a hill the thrust of the wheels is reversed. Slippage occurring in this circumstance will result in cracks pointing uphill.

1. CAUSE

Slippage cracks are caused by the lack of a good bond between the surface layer and the course beneath. The lack of bond may be due to dust, oil, rubber, dirt, water, or other non-adhesive material between the two courses. Usually, such a lack of bond exists when no tack coat has been used. Slippage cracks may also be due to a mixture having a high sand content, and they can occur whether the sand is sharp or rounded. Sometimes slippage may develop under traffic because improper compaction during construction caused the bond layers to be broken.

2. REPAIR

The only proper way to repair a slippage crack is to remove the surface layer from around the crack to the point where good bond between the layers is found. Then patch the area with plant-mixed asphalt material.

- (a) Remove the slipping area and at least (0.3 meter) one foot into the surrounding well bonded pavement. Make the cut faces straight and vertical. A power pavement saw makes a fast and neat cut. Figure 19.

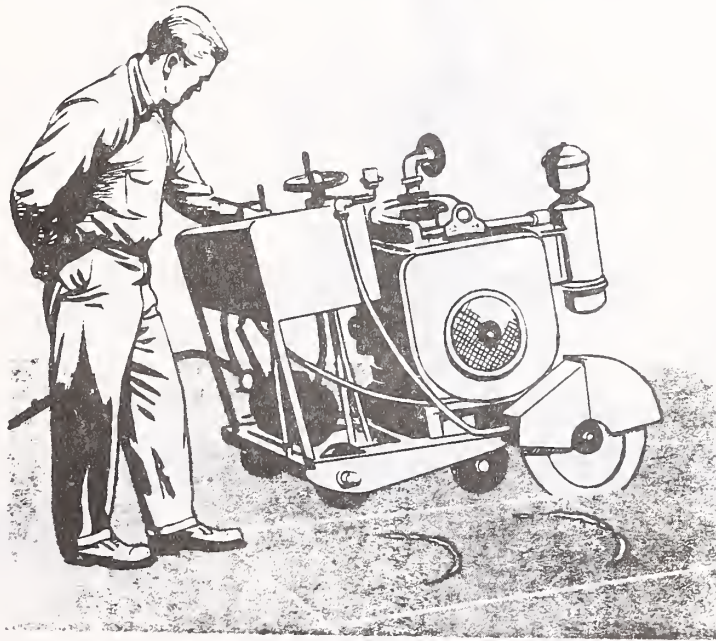


Figure 19. Cutting with power saw.

- (b) Clean the surface of the exposed underlying layer with brooms and compressed air. Figure 20.

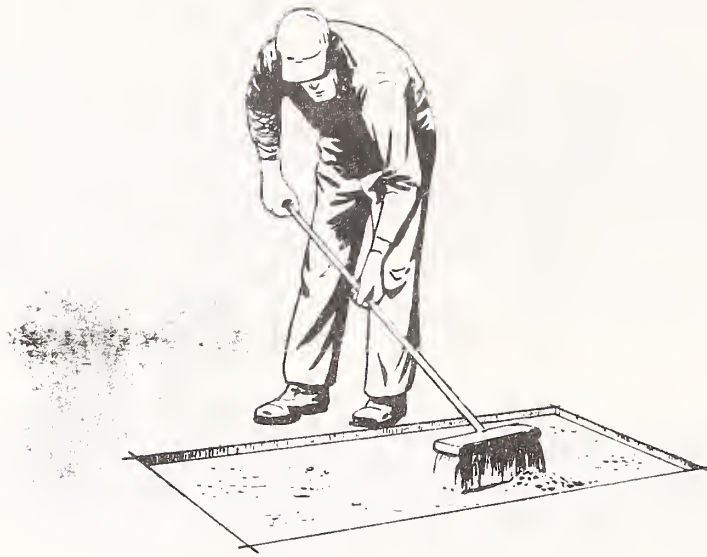


Figure 20. Cleaning surface of exposed layer.

(c) Apply a light tack coat. Figure 21.

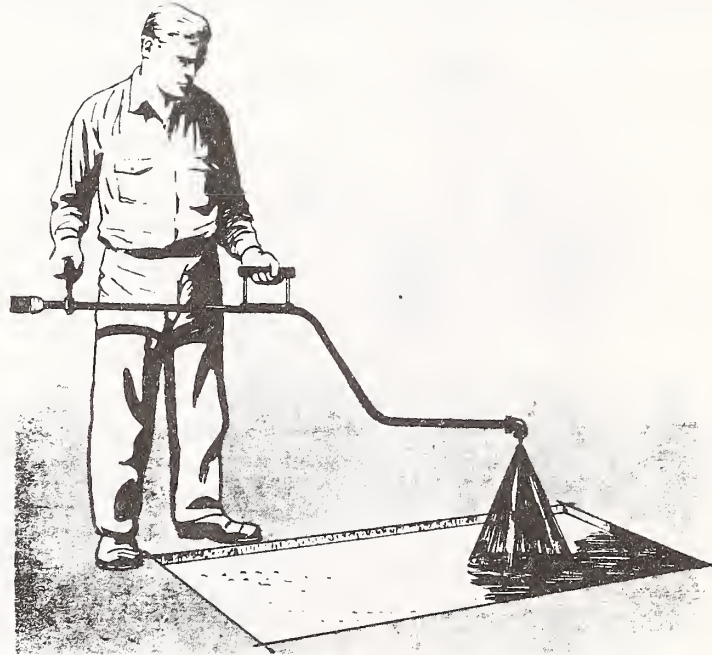


Figure 21. Applying a tack coat.

(d) Place enough hot plant-mixed asphalt material in the cutout area to make the surface the same grade as the surrounding pavement when it is compacted. Figure 22.



Figure 22. Placing plant-mix in cut.

- (e) Level the mixture carefully to prevent segregation.
Figure 23.



Figure 23. Leveling patch mixture.

- (f) Check the riding quality of the patch with a straight-edge or a stringline. Figure 24.

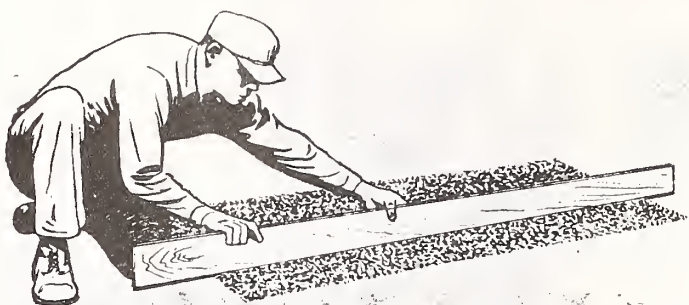


Figure 24. Checking with straightedge.

- (g) Compact thoroughly with a vibrating plate compactor or a steel-wheeled roller. Figure 25.



Figure 25.

WIDENING CRACKS

Widening cracks are longitudinal reflection cracks that show up in the asphalt overlay above the joint between the old and new sections of a pavement widening.

1. CAUSE

See Reflection Cracks

2. REPAIR

See Reflection Cracks

DISTORTION

GENERAL

Pavement distortion is any change of the pavement surface from its original shape. It usually is caused by such things as too little compaction of the pavement courses, too many fines in surface mixtures, too much asphalt, swelling of underlying courses, or settlement. Like cracks, distortion takes a number of different forms: grooves or ruts, shoving, corrugations, depressions, upheaval. As with any other defect, the type of distortion and its cause must be determined before the correct remedy can be applied. Repair techniques range from leveling the surface by filling with new material to complete removal of the affected area and replacing with new material.

CHANNEL (RUTS)

These are channelized depressions which may develop in the wheel tracks of an asphalt pavement.

1. CAUSE

Channels may result from consolidation or lateral movement under traffic in one or more of the underlying courses, or by displacement in the asphalt surface layer itself. They may develop under traffic in new asphalt pavements that had too little compaction during construction. They may develop from plastic movement in a mix that does not have enough stability to support the traffic.

2. REPAIR

Level the pavement by filling the channels with hot plant-mixed asphalt material. Follow with a thin asphalt plant-mix overlay.

- (a) Determine the limits of channels with a straightedge or stringline. Outline with a crayon the areas to be filled.
- (b) Apply a light tack coat, (0.2 to 0.7 litre/m²) 0.05 to 0.15 gal/yd² of SS-1, SS-1h, CSS-1, or CSS-1h asphalt emulsion diluted with equal parts of water.
- (c) Spread dense-graded asphalt concrete in the channels with a paver. Be sure that the material is feathered at the edges.

- (d) Compact with a pneumatic-tired roller. If one is not available, use a steel-wheeled roller.
- (e) Place a thin overlay of hot plant-mixed material.
- (f) If the pavement is not to be overlaid, place a sand seal over the patched areas to prevent the entrance of water, being careful not to apply too much asphalt.

CORRUGATIONS AND SHOVING

Corrugations (sometimes called "washboarding") is a form of plastic movement typified by ripples across the asphalt pavement surface. Shoving is a form of plastic movement resulting in localized bulging of the pavement surface. These occur usually at points where traffic starts and stops, on hills where vehicles brake on the downgrade, on sharp curves, or where vehicles hit a bump and bounce up and down.

1. CAUSE

Corrugations and shoving usually occur in asphalt layers that lack stability. Lack of stability may be caused by a mixture which is too rich in asphalt, has too high a proportion of fine aggregate, has coarse or fine aggregate which is too round or too smooth textured, or has asphalt cement which is too soft. It may also be due to excessive moisture, contamination due to oil spillage, or lack of aeration when placing mixes using liquid asphalts.

2. REPAIR

If the corrugated pavement has an aggregate base with a thin surface treatment, a satisfactory corrective measure is to scarify the surface, mix it with the base, and recompact the mixture before resurfacing.

If the pavement has more than (5 cm) 2 in. of asphalt surfacing and base, shallow corrugations can be removed with a pavement planing machine, better known as a "heater-planer." This is followed with a seal coat or plant-mixed surface.

For effective repair, shoved areas must be removed and patched.

REPAIR OF CORRUGATIONS IN A THIN SURFACE TREATMENT:

- (a) Scarify and break up the surface with a rotary tiller.

- (b) Mix the broken-up surface material with the base material to a depth of (10 cm) 4 in.
- (c) Compact and reshape the base.
- (d) Prime the base.
- (e) Apply a new surface treatment.

REPAIR OF CORRUGATIONS IN A THICK ASPHALT SURFACE:

- (a) Plane to a smooth surface with a heater-planer. If a paved gutter line must be met, cut a shoulder with the heater-planer. The shoulder should be the thickness of the seal coat to follow, so that the edges will not have to be feathered.
- (b) Cover the planed surface with a hot plant-mixed asphalt seal coat or an asphalt emulsion slurry seal (or an asphalt concrete overlay if one is needed).

GRADE DEPRESSIONS

Depressions are localized low areas of limited size which may or may not be accompanied by cracking. They dip (several centimeters) an inch or more below grade and water will collect in them.

These "birdbaths" are not only a source of pavement deterioration but are a hazard to motorists, especially in freezing weather.

1. CAUSE

Depressions may be caused by traffic heavier than that for which the pavement was designed, by settlement of the lower pavement layers, or by poor construction methods.

2. REPAIR

Depressions should be filled with hot plant-mixed asphalt material and compacted to bring them up to the same grade as the surrounding pavement.

- (a) Determine the limits of the depression with a straight-edge or stringline. Outline it on the pavement surface with a marking crayon. Figure 26.

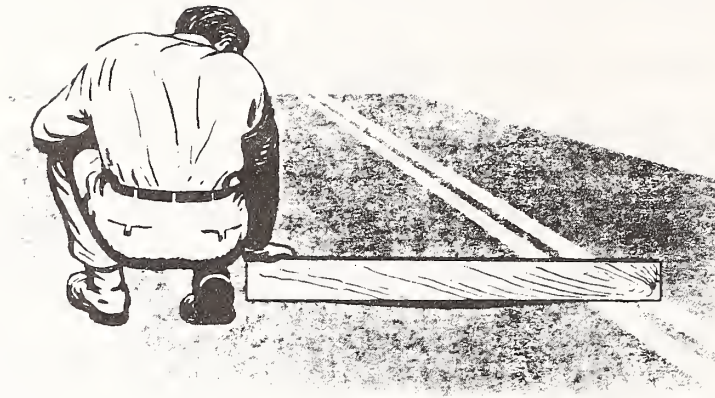


Figure 26. Straightedging and outlining depression.

- (b) If grinding equipment is available, grind down the area to provide a vertical face around the edge. If this equipment is not available, this step may be omitted. Figure 27.

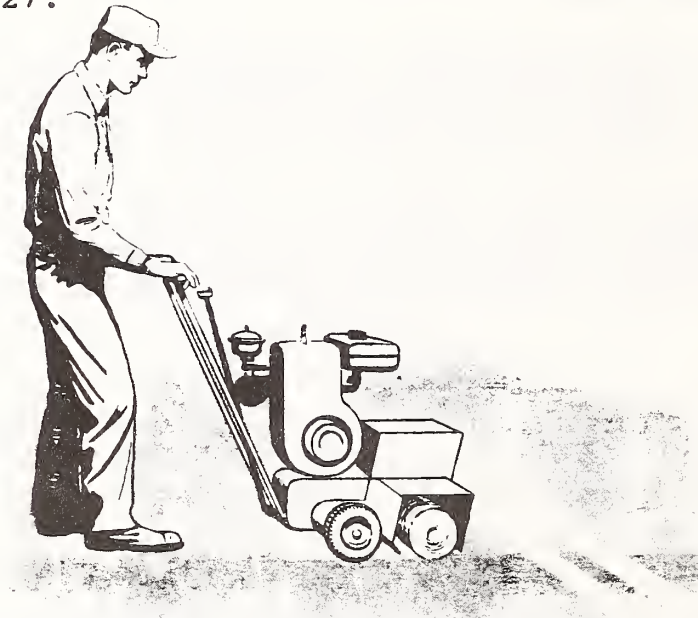


Figure 27. Grinding down edge.

- (c) Thoroughly clean the entire area to at least (0.3 meter) a foot beyond the marked limits. Figure 28.



Figure 28. Cleaning area.

- (d) Apply a light tack coat, (0.2 to 0.7 litre/m²) 0.05 to 0.15 gal/yd² of SS-1, SS-1h, or CSS-1h asphalt emulsion diluted with equal parts of water to the cleaned area. Figure 29.



Figure 29. Applying tack coat.

- (e) Allow the tack coat to cure.

- (f) Spread enough hot plant-mixed asphalt material in the depression to bring it to the original grade when compacted. Figure 30. Plant mix with cutback or emulsified asphalt (cold-laid) may be used if the hot mix is not available. If the mixture is the cold-laid type, it should be aerated thoroughly before it is placed in the depression. This is necessary to get rid of solvents and water that may cause an unstable patch.



Figure 30. Spreading plant-mix.

- (g) If the pavement was not ground down, the edges of the patch should be feather-edged by careful raking and manipulation of the material. However, in raking, care should be taken to avoid segregation of the coarse and fine particles of the mixture.
- (h) Check the patch with a straightedge or a stringline. Figure 31.

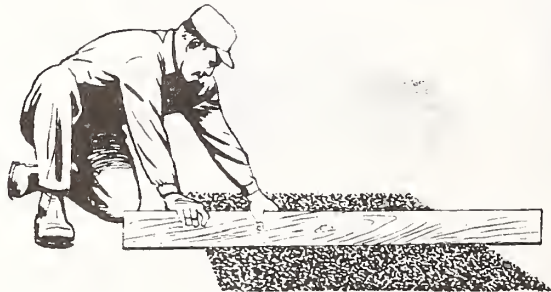


Figure 31. Straightedging patch.

- (i) Thoroughly compact the patch with a vibratory plate compactor, roller, or hand tamps. Figure 32.

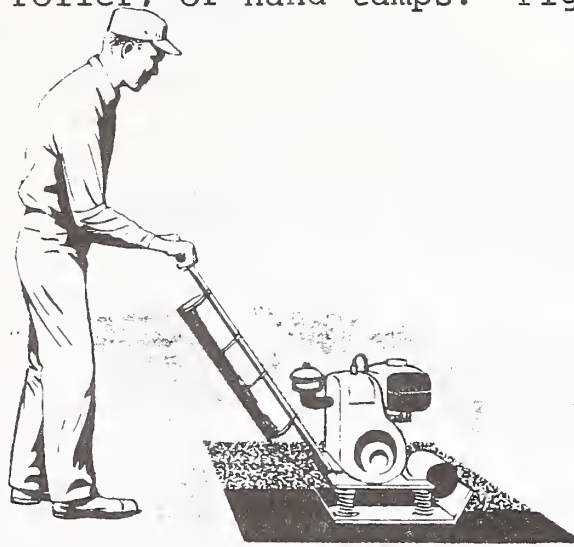


Figure 32. Compacting patch.

- (j) Place a sand seal on the patched area to prevent the entrance of water. Do not apply too much asphalt.

UPHEAVAL

Upheaval is the localized upward displacement of a pavement due to swelling of the subgrade or some portion of the pavement structure. Frost heaves are good examples.

1. CAUSE

Upheaval is most commonly caused by expansion of ice in the lower courses of the pavement or the subgrade. But it may also be caused by the swelling effect of moisture on expansive soils.

2. REPAIR

See Alligator Cracks - Deep Patch

UTILITY CUT DEPRESSIONS

Depressions in the pavement that develop from a cut for utility installation or repair.

1. CAUSE

These depressions usually are caused by lack of adequate compaction of backfill.

2. REPAIR

See Depressions

DISINTEGRATION

GENERAL

Disintegration is the breaking up of a pavement into small, loose fragments. This includes the dislodging of aggregate particles. If not stopped in its early stages, it can progress until the pavement requires complete rebuilding.

Two of the more common types of early-stage disintegration are pot holes and raveling. Repair ranges from simple seals to deep patching.

The repair techniques recommended in this section are not necessarily the only correct ways to do the job. They are, however, proven methods that will give satisfactory results.

POT HOLES

These are bowl-shaped holes of various sizes in the pavement resulting from localized disintegration.

1. CAUSE

Pot holes are usually caused by weakness in the pavement resulting from such as too little asphalt, too thin an asphalt surface, too many fines, too few fines, or poor drainage.

2. REPAIR

Pot holes frequently appear when it is difficult to make a permanent repair and emergency measures have to be taken. Temporary repair usually involves cleaning out the hole and filling it with a premixed asphalt patching material. Permanent repair (Figure 33) is made by cutting out the hole to solid material on both sides and bottom and filling it with new base and surface material.

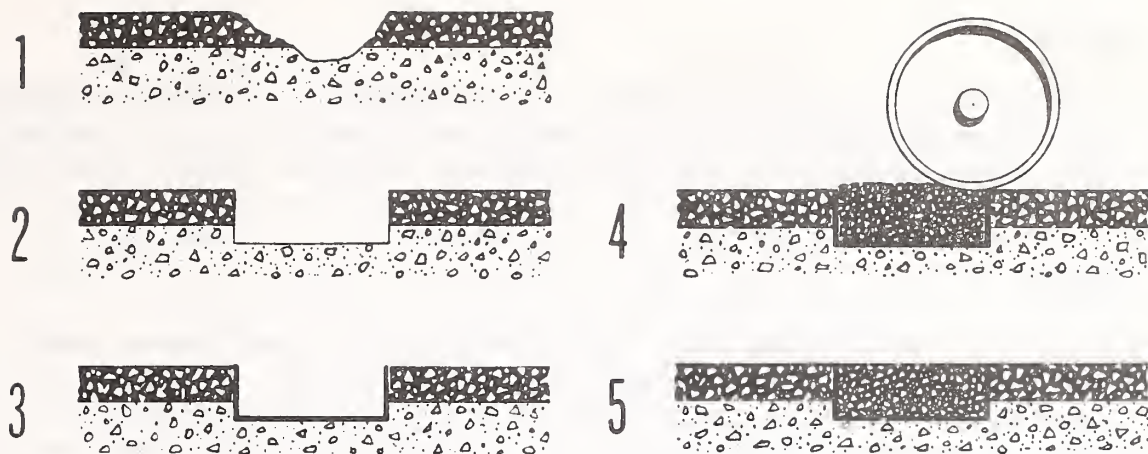


Figure 33.

Pot hole permanent repair. (1) Untreated pot hole, (2) Surface and base removed to firm support, (3) Tack coat applied, (4) Full-depth asphalt mixture placed and being compacted, (5) Finished patch compacted to level of surrounding pavement.

EMERGENCY REPAIR:

- (a) Clean hole of loose material and as much water as possible.
- (b) Use infra-red heater to heat and soften asphalt surfacing surrounding hole.
- (c) Fill hole with asphalt emulsion stockpile mixture and rake smooth.
- (d) Compact with vibratory plate compactor or roller.
- (e) Dry compacted patch with infra-red heater.

PERMANENT REPAIR: See Alligator Cracks - Deep Patch.

RAVELING

This is the progressive separation of aggregate particles in a pavement from the surface downward or from the edges inward. Usually, the fine aggregate comes off first and leaves little "pock marks" on the pavement surface. As the erosion continues, larger and larger particles are broken free and the pavement soon has the rough and jagged appearance typical of surface erosion.

1. CAUSE

Raveling is caused by lack of compaction during construction, construction during wet or cold weather, dirty or disintegrating aggregate, too little asphalt in the mix, or overheating of the asphalt mix.

2. REPAIR

Raveling surfaces, dry and weathered surfaces, and porous surfaces are conditions which usually require a surface treatment. These treatments may be looked upon either as corrective maintenance or as preventive maintenance. In the former case they are used to correct an existing condition. In the latter case they are used in an effort to prevent an anticipated condition from becoming a reality.

EMERGENCY REPAIR

- (a) Sweep the surface free of all dirt and loose aggregate material.
- (b) Apply a fog seal, (0.45 to 0.9 liter/m²) 0.1 to 0.2 gal/yd², depending upon the texture and porosity of the pavement, of SS-1h or CSS-1h asphalt emulsion diluted with equal parts of water. Cover aggregate is not required.
- (c) Close to traffic until seal has cured.

PERMANENT REPAIR

- (a) Same as (a), (b), and (c) for Emergency Repair.
- (b) Apply a surface treatment (slurry seal, sand seal, aggregate seal, or plant-mixed surface treatment, depending on the condition of the surface and the amount of traffic).

SKID HAZARD

GENERAL

Few dry pavements are slippery. But there are a number of things that can make a pavement slippery when wet. One of the most frequent causes of slippery asphalt pavements is a thin film of water on a smooth surface. Another if a thick film of water which, as high speeds, causes the vehicle to leave the pavement surface and skim over the water like an aquaplane. The smooth

pavement condition usually is the result of a film of asphalt on the surface, or polished aggregate in the surface course. Slipperiness may also develop from surface contamination, such as from oil spillage or certain types of clay. The object of skid hazard improvement is to restore the pavement surface to a condition where water can flow around most of the surface aggregate particles, leaving contact between tire and aggregate. Treatment ranges from cleaning the surface of contamination to removal of excess asphalt and resurfacing to improve surface drainage.

BLEEDING OR FLUSHING ASPHALT

Bleeding, or flushing, is the upward movement of asphalt in an asphalt pavement resulting in the formation of a film of asphalt on the surface.

1. CAUSE

The most common cause of bleeding, or flushing, which usually occurs in hot weather, is too much asphalt in one or more of the pavement courses. This can result from too rich a plant mix, an improperly constructed seal coat, too heavy a prime or tack coat, or solvent carrying asphalt to the surface. Also, overweight traffic may cause added compression of a pavement, containing too much asphalt, forcing it to the surface.

2. REPAIR

In many cases, bleeding can be corrected by repeated applications of hot sand, hot slag screenings, or hot rock screenings to blot up the excess asphalt. Sometimes, when bleeding is light, a plant-mixed surface treatment or an aggregate seal coat, using absorptive aggregate, is the only treatment needed. Or a hot plant-mixed leveling course with a low asphalt content can be effective in absorbing the excess asphalt. With this treatment, however, a new surface is needed over the leveling course to prevent raveling.

A pavement planing machine, such as a heater-planer, will remove the excess asphalt. Or in rare instances of heavily over-asphalted surfaces, the surfaces should be completely removed.

REPAIR WITH HOT AGGREGATE

- (a) Apply (9.5 mm) 3/8 in. maximum size slag screenings, sand, or rock screenings to the affected area. The aggregate should be heated to at least (150°C) 300°F and spread at the rate of (5.4 to 8 kg/m²) 10 to 15 lb/yd².

- (b) Immediately after spreading, roll with a rubber-tired roller.
- (c) When the aggregate has cooled, broom off loose particles.
- (d) Repeat the process, if necessary.

REPAIR WITH A HEATER-PLANER

- (a) Remove the asphalt film with a heater-planer.
- (b) Leave the surface as planed, or
- (c) Apply either a plant-mixed surface treatment or a seal coat.

POLISHED AGGREGATE

These are aggregate particles in the surface of a pavement that have been polished smooth. This includes both naturally smooth uncrushed gravels and crushed rock that wears down quickly under the action of traffic.

1. CAUSE

Some aggregates, particularly some types of limestone, will become polished rather quickly under traffic. Others, such as some types of gravel are naturally polished and if they are used in a pavement surface without crushing they will be a skid hazard. These polished aggregates are quite slippery when wet.

2. REPAIR

The only effective way to repair a pavement with polished aggregates is to cover the surface with a skid resistant treatment. A hot plane-mixed surface treatment, a sand seal, or an aggregate seal should be applied. The aggregate must be hard and angular, such as slag silica sand, or other proven non-polishing material.

PLANT-MIXED SURFACE TREATMENT

- (a) Apply a light tack coat, (0.2 to 0.7 liter/m²) 0.05 to 0.15 gal/yd² of SS-1, SS-1h, CSS-1, or CSS-1h asphalt emulsion diluted with equal parts of water.
- (b) Spread hot plant-mixed material using aggregate such as crushed slag or silica sand. If the hot plant-mixed

material is not available, a sand or an aggregate seal may be used.

- (c) Roll with rubber-tired and steel-wheeled rollers.

SURFACE TREATMENT - SPECIAL PROBLEMS

GENERAL

Because of the method of construction, surface treatments may develop some defects that do not occur in other types of asphalt pavement surfaces. These include loss of cover aggregate and streaking.

Some of the other asphalt pavement defects described earlier in this chapter - corrugations, depressions, upheaval, pot holes, and raveling - occur most frequently in pavements constructed by surface-treated methods. This happens because the thin asphalt surfacing usually is placed over an underdesigned pavement structure.

LOSS OF COVER AGGREGATE

The whipping-off of aggregate under traffic from a surface-treated pavement, leaving the asphalt.

1. CAUSE

Several things can cause the loss of cover aggregate. If the aggregate is not spread immediately (within one minute) after the asphalt is applied to the pavement surface the asphalt may have cooled too much to hold it. If the aggregate is too dusty or too wet when spread the asphalt may not be able to hold it under traffic. If the freshly-spread aggregate is not rolled immediately after placing, it may not become seated in the asphalt sufficiently to hold under traffic. Or, if a steel-wheeled roller alone is used for compaction, aggregate may be lost from low spots that are bridged over by the roller. Other reasons are: weather too cool when treatment was applied; fast traffic too soon on the new surface treatment; and a surface which absorbs part of the asphalt leaving too little to hold the aggregate.

2. REPAIR

Hot coarse sand, spread over the affected areas, may be used to replace the lost aggregate. After spreading, it should be rolled immediately with a pneumatic-tired roller so that it

will be seated into the asphalt. If the aggregate is only partially whipped-off, an absorptive aggregate seal may be the most practical treatment.

- (a) On a hot day, spread coarse sand, heated to at least (150°C) 300°F, over the area that has lost cover aggregate.
- (b) Follow immediately (before sand has a chance to cool even a few degrees) with a pneumatic roller to seal the aggregate in the asphalt.

LONGITUDINAL STREAKING

Alternating lean and heavy lines of asphalt running parallel to the centerline of the road.

1. CAUSE

Several things can cause longitudinal streaking:

- (a) Spray bar on the asphalt distributor not set at the correct height for the spray fans to overlap properly.
- (b) Spray bar rising as load in distributor lightens.
- (c) Nozzle on spray bar not set at correct angle, not all set at same angle, are the wrong size, differ in size, some plugged with cold asphalt, or have imperfections.
- (d) Wrong asphalt pump speed.
- (e) Too cold asphalt.
- (f) Too low a pump pressure.

A single centerline streak may be caused by too little asphalt or too cold asphalt at the matching joint between two applications.

2. REPAIR

About the only satisfactory repair for longitudinal streaking is to plane off the streaked surface and apply a new surface treatment. It is much easier to prevent longitudinal streaking than to correct it. Careful adherence to the manufacturer's recommendations for the asphalt distributor before it is used and while it is being used will forestall streaking.

TRANSVERSE STREAKING

Alternating lean and heavy lines of asphalt running across the road which may result in corrugation in the pavement surface.

1. CAUSE

Transverse streaking is caused by spurts in the asphalt spray from the distributor spray bar. These spurts may be produced by pulsation of the asphalt pump due to worn or loose parts, by improper pump speed, or by a miss in the motor.

2. REPAIR

See Corrugations, and Longitudinal Streaking.

APPENDIX A

SUGGESTED SPECIFICATIONS FOR STOCKPILE PATCHING MIXTURES

PLANT-MIXED ASPHALT STOCKPILE MAINTENANCE MIXTURES

SCOPE

Furnish stockpile asphalt maintenance mixture as specified.

GENERAL REQUIREMENTS

EQUIPMENT

The equipment shall include an asphalt mixing plant designed, coordinated, and operated to produce a uniform mixture within the job-mix tolerances.

SAMPLES

Samples for all materials proposed for use under these specifications shall be submitted to the engineer for test and analysis. The material shall not be used until it is approved by the engineer.

Sampling of asphaltic materials shall be in accordance with the latest revision of AASHTO Designation T 40 (ASTM Designation D 140). Sampling of mineral aggregate shall be in accordance with the latest revision of AASHTO Designation T 2 (ASTM Designation D 75).

METHODS OF TESTING

1. Asphaltic materials will be tested by the methods of test of the American Association of State Highway and Transportation Officials (AASHTO). If an AASHTO method of test is not available, the American Society for Testing and Materials (ASTM) method will be used.
2. Mineral aggregates will be tested by one or more of the following methods of test of the American Association of State Highway and Transportation Officials (AASHTO). If an AASHTO method of test is not available, the American Society for Testing and Materials (ASTM) method will be used.

METHODS OF TESTING AGGREGATE MATERIALS

Characteristic	Method of test	
	AASHTO	ASTM
Abrasion of Coarse Aggregate, Los Angeles Machine	T 96	C 131
Sieve Analysis, Fine and Coarse Aggregates	T 27	C-136
Unit Weight of Aggregate	T 19	C 29
Sand Equivalent	T 176	D 2419

MATERIALS

ASPHALT

The asphalt shall be MC-250, MC-800, SC-250, SC-800, CMS-2 or CMS-2h, as specified by the engineer prior to letting the contract. The grade of asphaltic material specified shall meet the requirements for that grade in the applicable table of Specifications for Paving and Industrial Asphalts, Specification Series No. 2 (SS-2), The Asphalt Institute.

MINERAL AGGREGATE

The mineral aggregate shall be crushed stone, crushed or uncrushed gravel, slag, sand, stone or slag screenings, mineral dust or a combination of any of these materials meeting one of the gradations shown below:

MINERAL AGGREGATE GRADATIONS

Sieve Sizes	Mix Designation and Nominal Maximum Size of Aggregate		
	3/8 in. (9.5 mm)	1/2 in. (12.5 mm)	3/4 in. (19.0 mm)
25.0 mm (1 in.)	-	-	100
19.0 mm (3/4 in.)	-	100	90-100
12.5 mm (1/2 in.)	100	90-100	-
9.5 mm (3/8 in.)	90-100	-	56-80
4.75 mm (No. 4)	55-85	44-74	35-65
2.36 mm (No. 8)	32-67	28-58	23-49
300.0 μ m (No. 50)	7-23	5-21	5-19
75.0 μ m (No. 200)	2-10	2-10	2-8

CONSTRUCTION

PREPARATION OF MIXTURE

Coarse and fine aggregate shall be fed into the plant in the proportions required to provide a total aggregate conforming with the grading specified. The aggregate shall be free from visible moisture at the time of mixing. The asphalt shall be applied at the rate and at the temperature specified by the engineer to produce a final mixture containing from 4 to 6 percent liquid asphalt by weight of total mix. The mineral aggregate and the asphalt shall be mixed thoroughly until all aggregate particles are completely coated.

STOCKPILING

The finished mixture shall be stockpiled on a platform of (5 cm) 2 in. plank or other approved level storage space.

METHOD OF MEASUREMENT

The quantities to be paid for will be the total number of tons of asphalt maintenance mixture delivered to the stockpile.

IMPORTANT NOTICE

1. SELECTION OF ASPHALT

The following may be used as a guide for selecting the type and grade of asphalt for the stockpile mixture:

MC-250 - For immediate use under hot or moderate weather conditions, or for use within a short time after stockpiling.

MC-800 - For use within short time after stockpiling.

SC-250 - For long period storage in hot, dry climates.

SC-800 - For long period storage.

CMS-2 - Mix can be designed for use within a short time after stockpiling or for long storage period.

CMS-2h - Mix can be designed for use within a short time after stockpiling or for long storage period.

2. AMOUNT OF ASPHALT

The amount of asphalt required for the aggregate grading will normally be in the range of 4 to 6 percent by weight of total mix.

MIXED-IN-PLACE ASPHALT STOCKPILE MAINTENANCE MIXTURES

SCOPE

Furnish stockpile asphalt maintenance mixture as specified.

GENERAL REQUIREMENTS

EQUIPMENT

The equipment includes travel mixers; rotary mixers; motor graders; and an asphalt pressure distributor meeting the following requirements:

The pressure distributor shall be designed and operated to distribute the asphaltic material in a uniform spray without atomization.

The distributor shall be equipped with a bitumeter having a dial registering (meters) feet of travel per minute. The dial shall be visible to the truck driver so that he can maintain the constant speed required for application at the specified rate.

The pump shall be equipped with a tachometer having a dial registering (liters) gallons per minute passing through the nozzles. The dial shall be readily visible to the operator.

Means for indicating accurately the temperature of the asphaltic material in the distributor at all times shall be provided. The thermometer well shall not be in contact with, or close to, a heating tube.

The normal width of application of the spray bar shall not be less than (3.7 meters) 12 feet, with provision for the application of lesser width when necessary. A hose spray and spray nozzle attachment shall be provided for applying asphaltic material to patches and areas inaccessible to the spray bar.

The distributor shall be equipped with heating attachments and the asphaltic material shall be circulated through the spray bar during the entire heating process.

Multiple-blade drags or other equipment may be used in addition to or in lieu of the specified mixing equipment when approved by the engineer.

SAMPLES

If any portion of the in-place road materials are to be used in the construction, the engineer will furnish the contractor with the test results and improvement requirements, if any, for the in-place materials. Samples of all other materials proposed for use under these specifications shall be submitted to the engineer for test and analysis. The material shall not be used until it is approved by the engineer.

Sampling of asphaltic materials shall be in accordance with the latest revision of Sampling Asphalt Products for Specification Compliance, MS-18, The Asphalt Institute. Sampling of mineral aggregate shall be in accordance with the latest revision of AASHTO Designation T 2 (ASTM Designation D 75).

ALTERNATE 2 - BLADE MIXING

PREPARATION OF MIXTURE

1. Coarse and fine mineral aggregate shall be deposited in a single windrow in the proportions required to provide a total aggregate conforming with the grading specified. After the proportions of coarse and fine aggregate are adjusted, the total loose aggregate shall be mixed thoroughly with a motor grader. It shall then be bladed into a single truncated windrow of uniform cross-section for measurement and adjustment as may be directed by the engineer.
2. Immediately prior to application of the asphalt, the windrow of mixed aggregate shall be bladed to a uniform cross-section approximately (5 cm) 2 in. thick. If damp, it shall first be bladed back and forth until surface dry. Upon the layer of graded aggregate, the asphalt shall be applied uniformly with the asphalt distributor at the temperature and at the rate specified by the engineer. The aggregate and asphalt shall be mixed as described in paragraph (3), following. Successive treatments of asphalt shall then be applied and mixed in the quantities, not exceeding (2.3 liters/m²) 1/2 gal/yd² each, directed by the engineer.
3. The motor grader shall follow the distributor immediately after each application of asphalt and shall continue to operate on the treated strip until all free asphalt is mixed into the aggregate. After the aggregate has received its total application of asphalt, mixing shall continue until a thoroughly uniform mixture is produced. If, before the process is completed, the mixture should become wet, the mixing operation shall be continued until it dries out. After final mixing the material shall be brought to a single windrow.

STOCKPILING

The finished mixture shall be stockpiled on a platform of (5 cm) 2 in. plank or other approved level storage space. When payment is to be made upon a cubic (meter) yard basis the stockpile shall be shaped to facilitate accurate volume measurement.

METHOD OF MEASUREMENT

The quantities to be paid for will be the total number of tonnes (tons) of asphalt maintenance mixture delivered to the stockpile.

IMPORTANT NOTICE

1. Selection of Asphalt

The following may be used as a guide for selecting the type and grade of asphalt for the stockpile mixture:

MC-250 - For immediate use under hot or moderate weather conditions, or for use within short time after stockpiling.

MC-800 - For use within short time after stockpiling.

SC-250 - For long period storage in hot, dry climates.

SC-800 - For long period storage.

CMS-2 - Mix can be designed for use within a short time after stockpiling or long storage period.

CMS-2h - Mix can be designed for use within a short time after stockpiling or for long storage period.

2. Amount of Asphalt

The amount of asphalt required for the aggregate grading specified will normally be in the range of 4 to 6 percent by weight of total mix.

3. Equipment

The blade-mixing portion of these specifications is written to require a motor grader for the mixing process. If other equipment, such as disk harrows and multiple blade drags, must be used they should be added.

CAUTION

The purpose of Tables IV-7 and IV-8 is to indicate temperature ranges necessary to provide proper asphalt viscosity for spraying and mixing applications for the grades of asphalt shown. It MUST be recognized however, that temperature ranges indicated by the charts generally are above the minimum flash point for the RC, MC and SC cutback asphalt materials. In fact, some of these cutback asphalts will "flash" at temperatures below these indicated ranges. Accordingly, suitable safety precautions are mandatory

TABLE IV-7 - TYPICAL TEMPERATURES FOR USES
OF ASPHALT - DEGREES CELSUIS (°C)

Type and Grade of Asphalt	Pugmill Mixture Temperatures ¹		Spraying Temperatures ⁵	
	Dense-Graded Mixes	Open-Graded Mixes	Road Mixes	Surface Treatments
Asphalt Cements				
AC-2.5	115-140	80-120	—	130 +
AC-5	120-145	80-120	—	140 +
AC-10	120-155	80-120	—	140 +
AC-20	130-165	80-120	—	145 +
AC-40	130-170	80-120	—	150 +
AR-1000	105-135	80-120	—	135 +
AR-2000	135-165	80-120	—	140 +
AR-4000	135-165	80-120	—	145 +
AR-8000	135-165	80-120	—	145 +
AR-16000	150-175	80-120	—	—
200-300 pen.	115-150	80-120	—	130 +
120-150 pen.	120-155	80-120	—	130 +
85-100 pen.	120-165	80-120	—	140 +
60-70 pen.	130-170	80-120	—	145 +
40-50 pen.	130-175	80-120	—	150 +
Emulsified Asphalts				
RS-1	—	—	—	20-60
RS-2	—	—	—	50-85
MS-1	10-70 ²	—	20-70	20-70
MS-2	10-70 ²	—	20-70	—
MS-2h	10-70 ²	—	20-70	—
HFMS-1	10-70 ²	—	20-70	20-70
HFMS-2	10-70 ²	—	20-70	—
HFMS-2h	10-70 ²	—	20-70	—
HFMS-2s	10-70 ²	—	20-70	—
SS-1	10-70 ²	—	20-70	—
SS-1h	10-70 ²	—	20-70	—
CRS-1	—	—	—	50-85
CRS-2	—	—	—	50-85
CMS-2	10-70 ²	—	20-70	—
CMS-2h	10-70 ²	—	20-70	—
CSS-1	10-70 ²	—	20-70	—
CSS-1h	10-70 ²	—	20-70	—
Cutback Asphalts (RC, MC, SC)³				
30 (MC only)	—	—	—	30 +
70	—	—	20 +	50 +
250	55-80 ⁴	—	40 +	75 +
800	75-100 ⁴	—	55 +	95 +
3000	80-115 ⁴	—	—	110 +

NOTES: Exact conversions from °F rounded to nearest 5°C.

- Temperatures for asphalt cements and cutback asphalts are guides only.

¹ Temperature of mixture immediately after discharge from the pugmill rather than temperature of asphalt cement or cutback asphalt.

² Temperature of the emulsified asphalt in the pugmill mixture.

³ Application temperature may, in some cases, be above the flash point of the material. Caution must therefore be exercised to prevent fire or an explosion.

⁴ Rapid-Curing (RC) grades are not recommended for hot pugmill mixing.

⁵ The maximum temperature (asphalt cement and cutback asphalt) shall be below that at which fogging occurs.

TABLE IV-8 - TYPICAL TEMPERATURES FOR USES
OF ASPHALT - DEGREES FAHRENHEIT (°F)

Type and Grade of Asphalt	Pugmill Mixture Temperatures ¹		Spraying Temperatures ⁵	
	Dense-Graded Mixes	Open-Graded Mixes	Road Mixes	Surface Treatments
Asphalt Cements				
AC-2.5	235-280	180-250	—	270 +
AC-5	250-295	180-250	—	280 +
AC-10	250-315	180-250	—	280 +
AC-20	265-330	180-250	—	295 +
AC-40	270-340	180-250	—	300 +
AR-1000	225-275	180-250	—	275 +
AR-2000	275-325	180-250	—	285 +
AR-4000	275-325	180-250	—	290 +
AR-8000	275-325	180-250	—	295 +
AR-16000	300-350	180-250	—	—
200-300 pen.	235-305	180-250	—	265 +
120-150 pen.	245-310	180-250	—	270 +
85-100 pen.	250-325	180-250	—	280 +
60-70 pen.	265-335	180-250	—	295 +
40-50 pen.	270-350	180-250	—	300 +
Emulsified Asphalts				
RS-1	—	—	—	70-140
RS-2	—	—	—	125-185
MS-1	50-160 ²	—	70-160	70-160
MS-2	50-160 ²	—	70-160	—
MS-2h	50-160 ²	—	70-160	—
HFMS-1	50-160 ²	—	70-160	70-160
HFMS-2	50-160 ²	—	70-160	—
HFMS-2h	50-160 ²	—	70-160	—
HFMS-2s	50-160 ²	—	70-160	—
SS-1	50-160 ²	—	70-160	—
SS-1h	50-160 ²	—	70-160	—
CRS-1	—	—	—	125-185
CRS-2	—	—	—	125-185
CMS-2	50-160 ²	—	70-160	—
CMS-2h	50-160 ²	—	70-160	—
CSS-1	50-160 ²	—	70-160	—
CSS-1h	50-160 ²	—	70-160	—
Cutback Asphalts (RC, MC, SC)³				
30 (MC only)	—	—	—	85 +
70	—	—	65 +	120 +
250	135-175 ⁴	—	105 +	165 +
800	165-210 ⁴	—	135 +	200 +
3000	180-240 ⁴	—	—	230 +

NOTES:

- Temperatures for asphalt cements and cutback asphalts are guides only.

¹ Temperature of mixture immediately after discharge from the pugmill rather than temperature of asphalt cement or cutback asphalt.

² Temperature of the emulsified asphalt in the pugmill mixture.

³ Application temperature may, in some cases, be above the flash point of the material. Caution must therefore be exercised to prevent fire or an explosion.

⁴ Rapid-Curing (RC) grades are not recommended for hot pugmill mixing.

⁵ The maximum temperature (asphalt cement and cutback asphalt) shall be below that at which fogging occurs.

at all times when handling these cutback asphalts. These safety precautions include, but are not limited to, the following:

1. Open flames or sparks must not be permitted close to these materials. Controlled heat should be applied in heating kettles, mixers, distributors, or other equipment designed and approved for the purpose.
2. Open flames must not be used to inspect or examine drums, tank cars, or other containers in which these materials have been stored.
3. All vehicles transporting these materials must be properly vented.
4. Only experienced personnel must be permitted to supervise the handling of these materials.
5. All applicable intrastate and interstate commerce requirements must be met.

APPENDIX B

FACTORS AFFECTING COMPACTION

Only with proper compaction will asphalt pavements provide the service life expected to them. Getting adequate compaction is so important that both contractor personnel and design engineers need to more fully understand the subject.

REASON FOR COMPACTING ASPHALT CONCRETE

Simply stated, the reason for compacting an asphalt concrete pavement is to enable it to carry traffic most efficiently for the longest time. This can only be achieved by forcing the aggregate particles of the mixture into close contact and then holding them in that position with the asphalt binder. The pavement will then have stability, cohesion, and impermeability.

STABILITY is the ability of the pavement to maintain or restore its equilibrium when acted upon by traffic loads tending to displace it. However, stability cannot be developed without the friction that results after compaction places the aggregate particles in close contact.

COHESION is the holding together of all of the parts of the pavement mass. It results from the coating of asphalt and filler material that acts as an adhesive. Cohesion imparts tensile strength. It resists the tensile stresses that may rupture the pavement. The degree of cohesion needed for effective pavement performance can only be obtained by adequate compaction which forces the particles together. This enables the asphalt binder to act on enough contact area of the aggregate to firmly hold it in place.

IMPERMEABILITY is the resistance of a pavement to the passage of water and air through it. Impermeability is achieved by making the pavement dense enough to prevent connecting voids in the mass. This can be done by proper compaction of well-designed mixes. Finally, the finished product can provide a tough, durable, and smooth roadway only if thorough and proper compaction has been achieved.

EFFECT OF MATERIAL PROPERTIES

Both the aggregate and the asphalt binder affect the compactability of the mix. While friction between aggregate particles is a major resistance to compaction, it is also a major factor providing stability of the compacted mat. This friction is a function of the surface texture of the aggregate, as well as its

overall shape. Aggregate particles with rough surfaces are difficult to move past each other, and produce high interparticle friction. This results in mixes that are somewhat harsh, and require greater energy for compaction than more workable mixes.

Aggregates with smooth surfaces have low interparticle friction, and move past each other easily under the compactive effort of the roller. Mixes of this type require lower compactive energy, and sometimes lighter rollers can be used.

The surface texture and angularity of the entire aggregate size range affect interparticle friction but the material passing the (9.5 mm) 3/8 inch sieve is particularly important. In general, crushing aggregate will increase texture roughness by exposing new faces. Crushed aggregates have more angular shapes, which contribute somewhat to the strength of compacted mixtures.

An aggregate's soundness and absorptive qualities are also important compaction consideration. Soft or unsound aggregates will break under steel-wheeled rollers, making it difficult to achieve density. Absorptive aggregates tend to take asphalt from the surface of the particles, thus drying the mix and making compaction difficult.

Aggregate gradation also affects compactability. A uniform grading provides the best mix for all-purpose use. It is the easiest mix to densify with the use of conventional compaction procedures. An excessive amount of coarse aggregate in the grading tends to make a harsh mix. As stated previously, a harsh mix requires greater energy for compaction, and sometimes is difficult to compact. Harsh mixes may require heavy rollers, particularly in the initial or breakdown pass.

An over-sanded mix tends to be too workable. The excess sand, especially if it is a natural rounded sand, acts like ball-bearings in the mix, making it easy to work but very difficult to compact. These mixes, particularly if they are high in the middle particle sizes, near the 600 m (No. 30) sieve, may be tender. Generally, lighter rollers and lower mix temperatures must be used in the compaction process because the mix tends to be lower in stability and is easily overstressed.

Filler in a mix is the fraction of the mineral aggregate that passes the 75 m (No. 200) sieve. Sufficient filler is necessary for the asphalt to develop adequate cohesion. And, if cohesion is low, the aggregate particles may not remain in intimate contact after compaction. If the filler content is too high, the mix may stiffen. Such a mix is hard to compact.

The asphalt and the filler in the mix combine to make the binder that holds the aggregate particles in place after compaction.

The binder provides the cohesion, which develops tensile strength in the mix. Cohesion increases substantially when the mix cools and the viscosity of the asphalt increases.

Asphalt viscosity affects compaction greatly. High viscosity tends to hold back movement of aggregate particles when the mix is rolled. If the viscosity is too low, the particles move easily during compaction, but not enough cohesion develops to hold the particles in position once compaction is completed. While hot, asphalt acts as a lubricant, overcoming the interparticle friction of the aggregate. Once the mix has cooled, asphalt acts as a binder holding the aggregate particles together.

The grade of asphalt determines the viscosity of the binder in the mix. Generally speaking, higher viscosity asphalts in a normal mix make it slightly more difficult to achieve required density, particularly in cool weather. Therefore, somewhat higher mix temperatures are necessary to reduce the viscosity during the compaction process, or possibly a softer grade of asphalt might be used. On the other hand, high viscosity asphalts are desirable for low stability mixes and for use in hot climates to hold the aggregate particles in place after rolling. Highly sanded mixes for example, particularly those with low filler content have lower cohesion, and are generally of lower stability. They may need an adjustment in the grade of asphalt or the rolling procedure to increase the viscosity of the asphalt enough for the mix to support the weight of the roller without horizontal displacement.

A mix having too little asphalt is difficult to compact. The low asphalt content results in poor lubrication and makes a dry, harsh mix. Not only is it more difficult to compact, the asphalt is unlikely to hold the particles for long. Air-void content in such a mix frequently is higher than desirable.

Too much asphalt lubricates the mix excessively, making it unstable and plastic under the roller. Normally, it is easy to achieve zero percent void content because all the voids in the mix will be filled with asphalt. The excess binder holds the aggregate particles too far apart, preventing the interparticle friction that gives the pavement stability.

EFFECTS OF COURSE THICKNESS

In general, it is easier to achieve required density in thicker lifts of asphalt concrete. Thick lifts hold heat longer, and so offer more time to compact. Rapid cooling of thin lifts, on the other hand, makes it essential that the roller get on the lift and complete the compaction process as rapidly as possible. As a consequence, mix temperatures generally should be higher for thin

lifts, 2 inches compacted or less, to allow enough time to complete the rolling operation. With thicker lifts, 3 inches compacted or greater, it is generally desirable to reduce the mix temperature somewhat. In thicker lifts, the lower temperature of the asphalt binder permits sufficient viscosity to develop in the binder soon enough to hold the particles in position.

The placement of pavement over yielding subgrades is definitely not recommended. But, when placement on yielding subgrades cannot be avoided, increased course thickness can be useful. Thicker lifts tend to protect the subgrade and allow compaction to be achieved, even though lighter rollers may be necessary. As soon as some degree of density is achieved in the thick lift on a yielding subgrade, a bridging effect develops in the mix. This permits additional courses to be placed and satisfactorily compacted. In effect, the first layer of asphalt concrete provides a platform against which subsequent layers can be compacted.

THE EFFECT OF MIX TEMPERATURES

Mix temperature is a principal factor affecting compaction. Compaction can only occur while the asphalt binder is fluid enough to act as a lubricant. When it cools enough to act as an adhesive, further rolling essentially becomes useless. The best time to roll an asphalt mixture is when its resistance to compaction is the least, while at the same time it is capable of supporting the roller without excessive shoving. The best rolling temperature is influenced by the interparticle friction of the aggregates, the gradation of the mix, and the viscosity of the asphalt.

Therefore, it can change if any of these factors change. The critical mix temperature in an asphalt concrete paving project is the temperature at the time of compaction. This should determine the temperature at which the plant is producing the mixture. At compaction, the mix temperature must be high enough to permit the movement of particles during the rolling operation. With harsher mixes, higher compaction temperatures and heavier rollers can be used. With most mixes, density can be increased by compaction as long as the mix temperature at a quarter- to a half-inch below the pavement surface is not less than 185°F. Target density will probably be attained at different temperatures for different mixes.

WEATHER CONDITIONS AFFECTING COMPACTION

Ambient, or air, temperature has a marked effect on compaction. The lower the air temperature, the faster the mix cools off. Lifts less than 2 inches in thickness should not be placed in cold weather, 40°F or less, because the mix cools too quickly for

densification to be accomplished by rolling. The mix temperature drops faster in thin lifts after the initial, or breakdown, pass of the roller than before rolling, particularly in cold weather. At lower ambient temperatures, thicker lifts can be used to place asphalt concrete in otherwise unsuitable conditions. Four-inch to 8-inch thick lifts can be placed in 30°F weather with satisfactory density achieved.

Wind is a major factor affecting compaction. The stronger the wind, the faster the mix cools, and it can become critical, particularly in cold weather. The cooling effect of wind also tends to produce a crust on the surface of the mix. This crust, normally from 3/8 to 1/2 inch in thickness, is a major factor in heat checking under the action of steel-wheeled rollers.

Another major contributor to the cooling of the mix is the temperature of the surface on which it is being placed. These temperatures have less of an effect on thick lifts as far as compaction is concerned. In thick lifts, the large mass of asphalt concrete retains the heat for a relatively long time even though ambient temperatures and surface temperatures are low.

The following graphs give combinations of mix placement and surface temperatures that normally will allow enough time to compact lifts to the required density. The graphs are based on data developed by Corlew and Dickson, and demonstrate heat loss in an asphalt layer under certain predetermined conditions. In producing this information, a set of typical properties for a particular hot asphalt mix was selected and assumed to remain constant. The results depicted on the graphs are conservative. Mix temperatures in other situations may possibly be lowered substantially and still provide time to achieve proper compaction.

EXAMPLE: A 3-inch compacted mat is to be placed on a surface having a temperature of 60°F. Enter each graph at a 3-inch mat thickness, and intersect the 60°F base temperature curve. This gives the following times for the asphalt to cool to 185°F:

Mix Temperatures	Time
300°F	35 minutes
275°F	29 minutes
250°F	22 minutes
225°F	14 minutes

Select the lowest mix temperature that will allow time to complete compaction with available equipment.

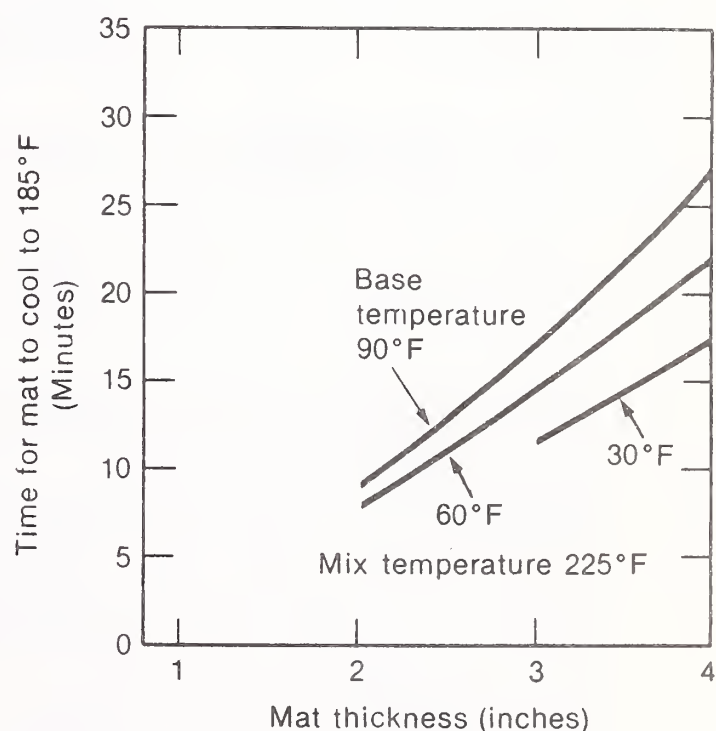
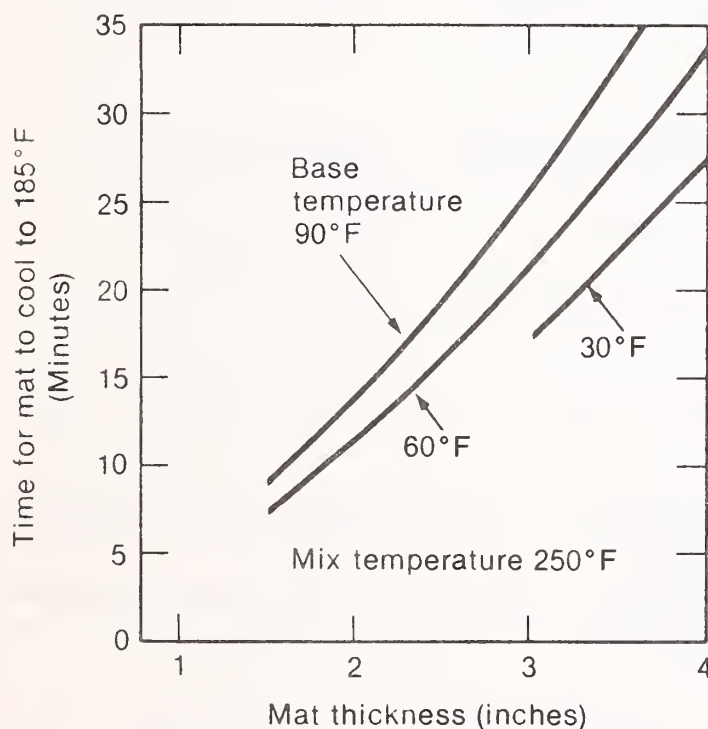
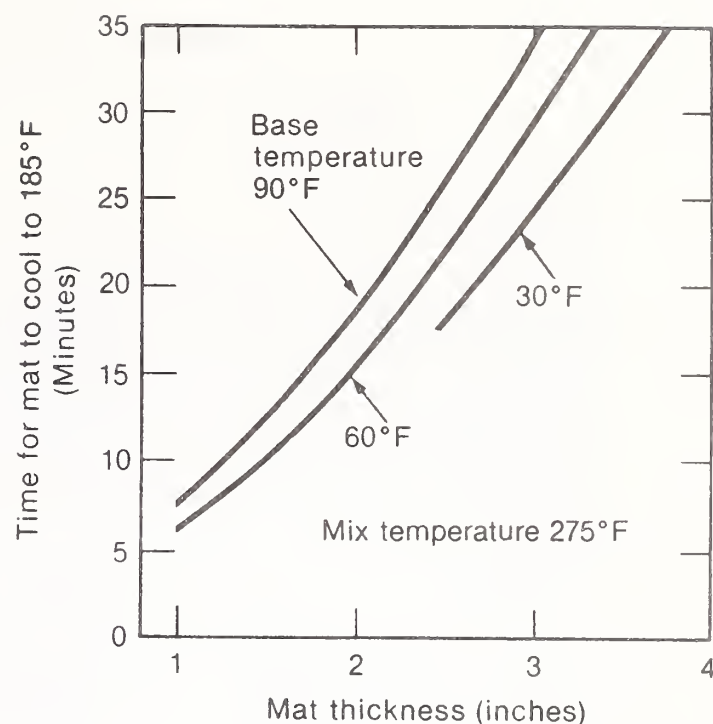
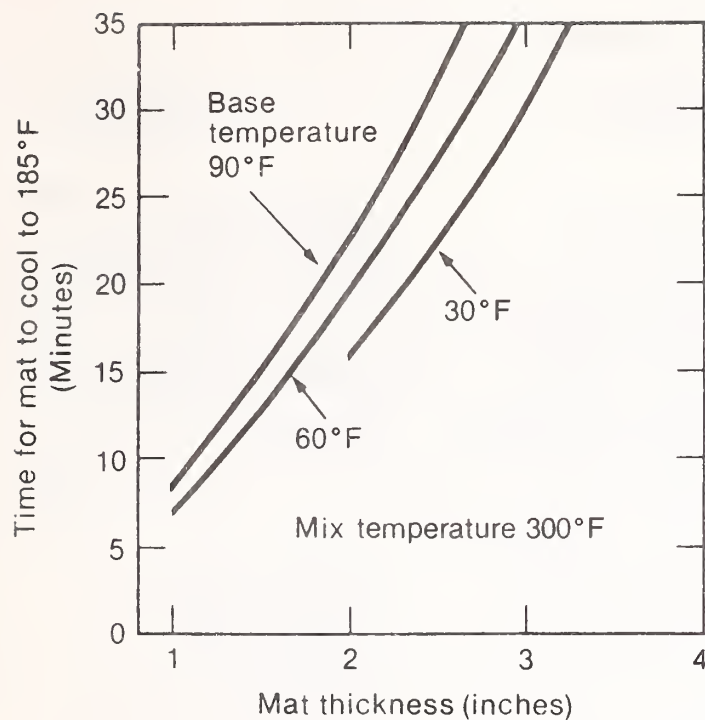


FIGURE 1 - TIMES FOR ASPHALT TO COOL TO 185°F.

Wind velocity-10 knots. Atmospheric temperature-same as base.

Note: "Base Temperature" is the temperature of the surface upon which the asphalt mat is placed.

* 185°F is the temperature of the mat measured 1/4 to 1/2 inch below the mat surface. The average temperature of the entire mat thickness when this temperature is reached, is approximately 175°F.

On a subgrade (base temperature) of 30°F, placing of thicknesses less than those shown on the curves is not recommended.

SUMMARY TABLE OF INFLUENCES OF COMPACTION*

ITEMS	EFFECTS	CORRECTIONS*
<i>Aggregate</i>		
• Smooth Surfaced	Low interparticle friction	Use light rollers Lower mix temperature
• Rough Surfaced	High interparticle friction	Use heavy rollers
• Unsound	Breaks under steel-wheeled rollers	Use sound aggregate Use pneumatic rollers
• Absorptive	Dries mix—difficult to compact	Increase asphalt in mix
<i>Asphalt</i>		
• Viscosity — High	Particle movement restricted	Use heavy rollers Increase temperature
— Low	Particles move easily during compaction	Use light rollers Decrease temperature
• Quantity — High	Unstable & plastic under roller	Decrease asphalt in mix
— Low	Reduced lubrication—difficult compaction	Increase asphalt in mix Use heavy rollers
<i>Mix</i>		
• Excess Coarse Aggregate	Harsh mix—difficult to compact	Reduce coarse aggregate Use heavy rollers
• Oversanded	Too workable—difficult to compact	Reduce sand in mix Use light rollers
• Too Much Filler	Stiffens mix—difficult to compact	Reduce filler in mix Use heavy rollers
• Too Little Filler	Low cohesion—mix may come apart	Increase filler in mix
<i>Mix temperature</i>		
• High	Difficult to compact—mix lacks cohesion	Decrease mixing temperature
• Low	Difficult to compact—mix too stiff	Increase mixing temperature
<i>Course Thickness</i>		
• Thick Lifts	Hold heat—more time to compact	Roll normally
• Thin Lifts	Lose heat—less time to compact	Roll before mix cools Increase mix temperature
<i>Weather Conditions</i>		
• Low Air Temperature	Cools mix rapidly	} Roll before mix cools Increase mix temperature Increase lift thickness
• Low Surface Temperature	Cools mix rapidly	
• Wind	Cools mix—crusts surface	

* Corrections may be made on a trial basis at the plant or job site. Additional remedies may be derived from changes in mix design.

COMPACTION FORCES

Figures B1 through B4 are schematic drawings of the presumed paths of forces within the pavement that are involved in compaction. They are intended to illustrate the principles involved rather than the exact conditions which exist. Figure B1 shows how the forces from an applied load act in an asphalt concrete mixture. It can be seen that the path of these forces is approximately circular. The dotted line shows the shape that the pavement surface will try to form under the load.

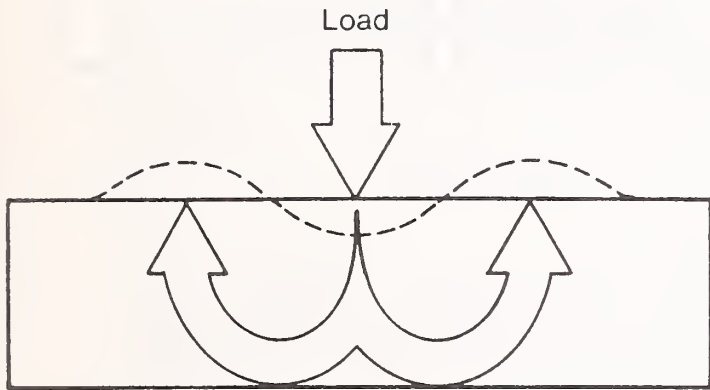


Figure B1.

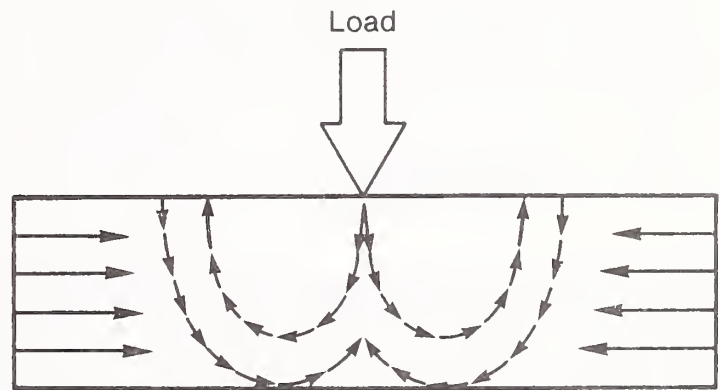


Figure B2.

It is necessary that an asphalt concrete mixture be confined before densification can take place. Figure B2 illustrates the confining forces in an asphalt mixture during compaction. The large arrow represents the load applied by a roller, either steel or pneumatic. The inner curved line of arrows directly under the large arrow represents the lines of force, and their paths within the mix resulting from the applied load. The outer curved line of arrows represents the forces in the mix that resist the movement of the particles. This resistance results principally from the interparticle friction of the aggregate in the mix, but is increased by the binder (asphalt and fines). The resisting forces of the binder increase as the temperature of the mix decreases. The horizontal arrows represent the confinement provided by the layer of the mix itself. The confining pressure provided by the mix increases as compaction proceeds, and as density is achieved. A great increase in confining pressure takes place when the temperature of the mix drops. This increased confining pressure results from the build-up of the viscosity and the consequent increase in cohesion of the mix itself.

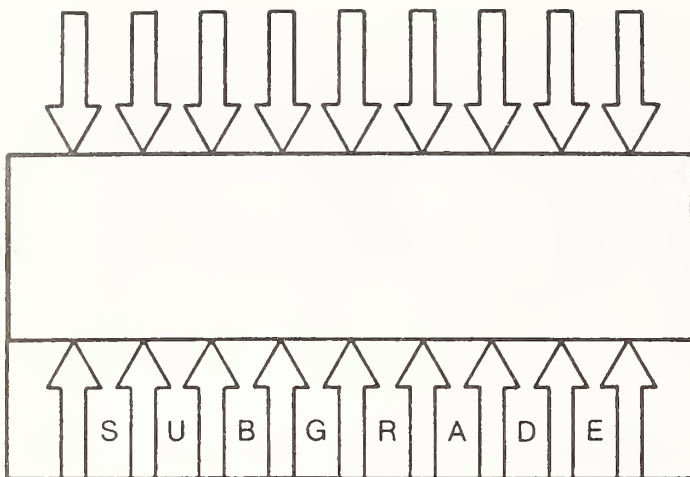


Figure B3.

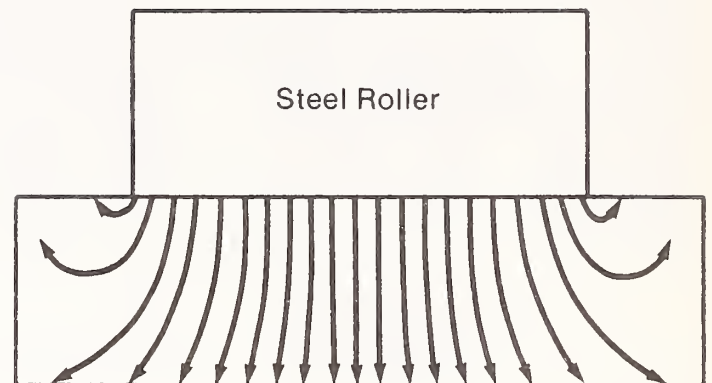


Figure B4.

Figure B3 illustrates the confinement at the top and bottom of a layer of asphalt concrete. The arrows at the top represent the pressure from a roller wheel. The arrows at the bottom represent the support provided by the subgrade. The subgrade must be firm, otherwise the confinement at the bottom of the mix will not be sufficient. It is not possible to satisfactorily compact an asphalt mixture against a yielding subgrade. If the subgrade is soft or yielding, it must be strengthened. The methods to do this are:

- a. To remove and replace the material in the yielding area.
- b. To stabilize the subgrade in the yielding area with an additive.
- c. To cover the yielding area with additional sound, untreated material.
- d. To bridge the yielding area with a layer of asphalt concrete placed in a single lift of sufficient thickness.

STEEL-WHEELED ROLLERS

Figure B4 illustrates the lines of force from a steel-wheeled roller on an asphalt concrete mixture placed on a firm subgrade. For the most part, the lines of force under the roller are resisted by the subgrade and by confinement within the mix itself. At the edges of the roller, however, the lines of force follow a somewhat circular pattern, as shown by the two outer arrows. These lines of force tend to thrust the asphalt mixture upward

and form a hump next to the edge of the roller. From this figure it can be seen that on a succeeding pass of the roller, the overlap of the steel wheel will only need to be wide enough to confine the mix that might have been upthrust by the forces represented by the two arrows coming from the edge of the roller. This distance will normally not exceed 3 to 4 inches.

Figure B5 illustrates a steel tandem roller being used incorrectly on an asphalt concrete mixture. The tiller wheel is in front in the direction of travel. This can be a critical mistake on some mixes, particularly during the breakdown pass. Since the tiller wheel is a dead wheel without power of its own, there is a tendency for it to push the mix away from itself, causing a wave in front. An analysis within the mix reveals two forces. One is a vertical force downward, and the other is a horizontal force forward. For compaction of a mix, the desirable movement of all aggregate particles is vertically downward. Little, if any, densification occurs as a result of horizontal movement within the mix. As a matter of fact, horizontal movement of the mix can actually result in a reduction of density.

Every effort should be made to minimize horizontal movement of the mix during compaction.

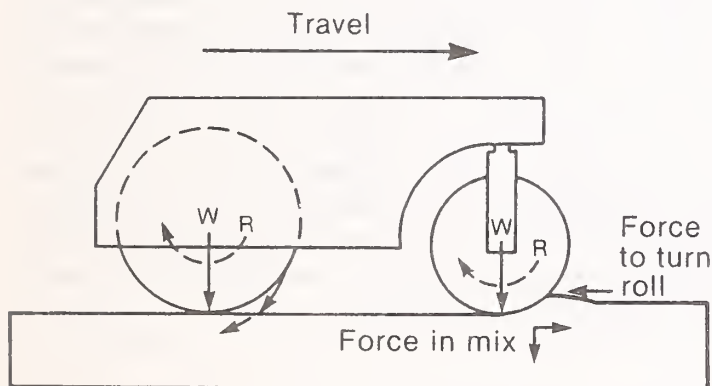


Figure B5.

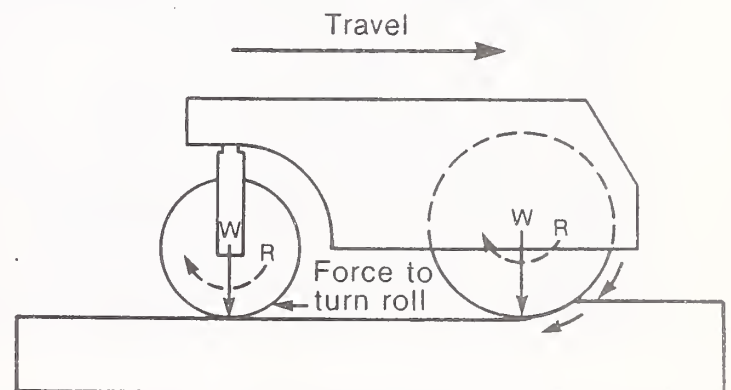


Figure B6.

Figure B6 illustrates the correct use of a steel-wheeled roller. The drive-wheel is ahead of the tiller wheel in the direction of travel on the uncompacted mix. It can be seen that there is a vertical force downward caused by the weight of the wheel. The arrows concentric with the steel wheel represent the rotational force on the wheel, which is transmitted to the mix as the roller is propelled. This concentric force tends to move the mix under the wheel rather than to push it away. The resultant of these forces is more nearly a direct vertical force than the resultant of the forces under the tiller wheel.

There are other reasons for the drive-wheel to be on the mix ahead of the tiller wheel, particularly during the breakdown pass of the roller. Since the drive-wheel has the largest diameter it presses with a flatter contact surface on the mix. Therefore, the horizontal force from the wheel has a larger diameter than the tiller wheel it does not sink as deep into the mix. This also reduces the horizontal component of force imparted by the wheel. The drive-wheel is the heaviest wheel and is considered to be the compaction wheel. Since the best time to compact is when the resistance is the least, while the mix is hot, the breakdown pass should be done with the compaction wheel on the mix first.

The weight of the roller is transmitted to mix through the contact pressure that is exerted under the wheels. Therefore, the contact pressure under the wheels should not exceed the supporting capability of the mix being compacted. Usually, heavier rollers can be used on harsher, more stable mixtures, particularly for breakdown passes. Somewhat lighter rollers might be necessary on less stable mixes.

Heat checking is a rather common occurrence during compaction of asphalt concrete mixes, particularly when the mix is placed in thin lifts. Figure B7 is a vertical side view of heat checking in a mix being compacted. Heat checking happens most frequently when the tiller wheel is in front in the direction of travel during the breakdown pass. The horizontal arrows shown between the surface of the mix and the dotted line represent the horizontal thrust of the tiller wheel in the mix. The curve to the right of the figure represents the temperature profile in a layer approximately 2 inches thick. The temperature at the surface is 250°F. The temperature at the mid-point is 290°F, while the temperature at the bottom is between 250 and 260°F.

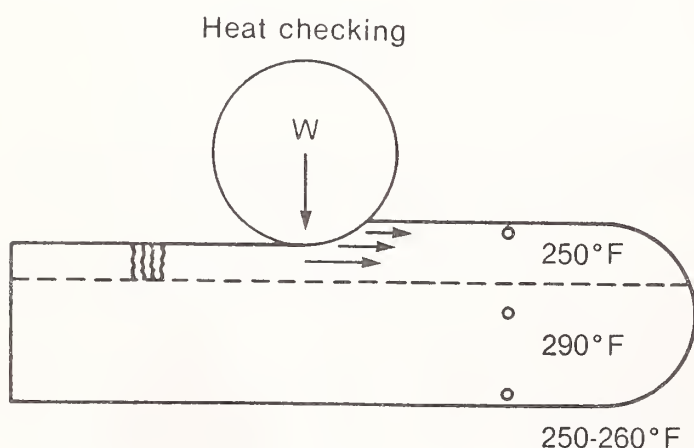


Figure B7.

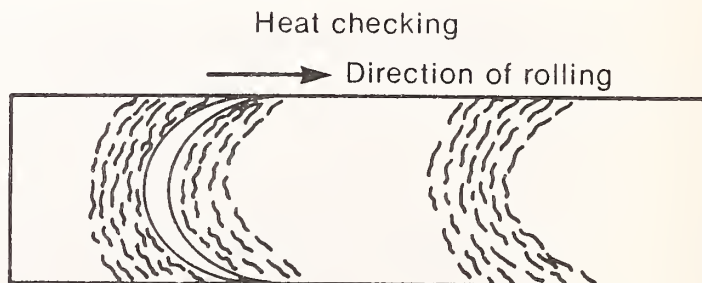


Figure B8.

The illustration shows the most frequent reason for heat checking. The tiller wheel has sunk some depth into the mix and is exerting a horizontal thrust which must be resisted by the mix itself. Since the mix is hottest at its mid-point, the asphalt viscosity is lower there than at the surface. Because of the horizontal force of the wheel, the mix tends to move horizontally at some depth (illustrated by the dotted line in the figure.) This means that the mix at the surface must also move. But the surface of the mix is stiffer due to its lower temperature, and responds by cracking in order to move along with the mix at the lower depth. This results in the so-called hairline cracks to the level that horizontal movement is occurring in the mix, generally $3/8$ to $1/2$ inch in depth. These are shown by the vertical lines behind the roller drum.

A plan view of the hairline cracks that result from heat checking is shown in Figure B8. They tend to be 3 to 4 inches long, unconnected with each other. If they were connected and extended, they would form a crescent as shown in this figure. A crescent-shaped crack in an asphalt mixture is typical of the slippage movement. This is exactly what happens under a roller when heat checking occurs with the slippage occurring in the mix at the depth shown by the dotted line in Figure 8, i.e., the mix is slipping within itself. As in any type of slippage distress, the crescent opens in the direction of the forces causing the slippage. In the case of heat checking, the hair crack pattern usually opens up in the direction of the rolling when the unpowered tiller wheel is leading.

The same type of crack pattern shown for heat checking can also occur if slippage is occurring at a greater depth, such as at the surface on which an asphalt lift is being placed. In this case, the cracks have the same general configuration. However, they are longer, open up wider, $1/4$ to 1 inch, and extend through the mix to the level of horizontal movement. Again slippage is occurring, but at a greater depth.

It is a rare case when heat checking occurs under a drive-wheel of a steel roller. It almost always occurs under the tiller wheel. Steel-wheeled rollers should not have the tiller wheel ballasted. The heavier the weight in the small diameter wheel, the deeper it sinks into the mix with a resulting increase of horizontal force being imparted during the rolling operation, and the greater likelihood of heat checking or other slippage distress.

PNEUMATIC-TIRED ROLLERS

There is a difference of opinion as to the benefits of pneumatic-tired rollers. Despite this, there are certain things that can

be done with pneumatic-tired rollers that cannot be done with static and vibratory steel-wheeled rollers. Pneumatic-tired rollers have been used successfully for compaction, both breakdown and secondary. They have also been found suitable for conditioning finished asphalt surfaces through the kneading action of the rubber tires. Although the two processes are different, each can be done successfully. The kneading action can only be achieved by pneumatic-tire rolling.

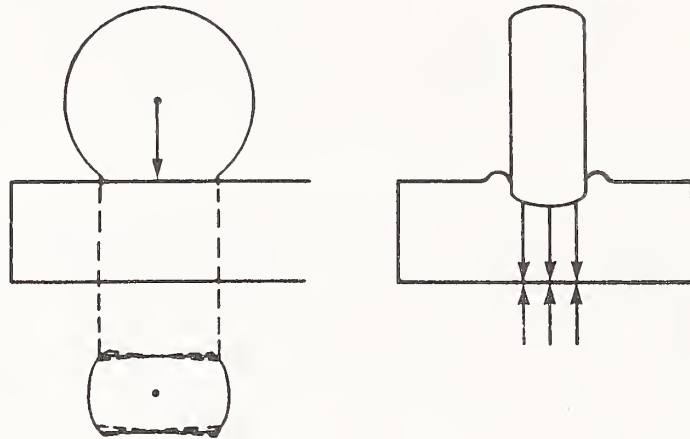


Figure B9.

Figure B9 illustrates the actions of a pneumatic-tired roller when used for either of the two processes mentioned above. The view on the left shows the kneading action of the tire on the compacted asphalt concrete surface. The view on the right indicates the forces acting under the pneumatic tire during compaction.

As in the case of the steel-wheeled rollers, it is necessary for the mix being compacted to be adequately confined in order for pneumatic-tired rollers to achieve density in the mix. A pneumatic-tired roller may be more critical than a steel-wheeled roller as far as a yielding subgrade is concerned because of the bridging effect of the rigid steel wheel.

Figure B5 illustrated the wave of material in front of a steel roller when the tiller was the first wheel on the mix during the breakdown pass. The movement of this wave is longitudinal in the mix. The wave extends all the way across the width of the roller. In the case of the pneumatic-tired roller, longitudinal movement of the mix will not take place unless the diameter of the tires is so small that the wheels sink very deep into the mix during the breakdown pass. If this happens, the particular pneumatic-tired roller is unsuited for breakdown rolling.

The wheel diameter has the same effect with pneumatic-tired rollers as it does with steel-wheeled rollers. Using larger

diameters, the weight of the roller presses with a flatter contact surface on the mix. The horizontal force from the tire is minimized during breakdown. As with the steel-wheeled roller, a tire with a large diameter does not sink as deep into the mix, which also reduces the horizontal force. The movement of the mix under a pneumatic tire tends to be lateral as shown in Figure B9. It may cause small humps in the mix immediately adjacent to the tire. These small humps normally are of no significance, and are rolled out with subsequent passes. As a matter of fact, compaction with a pneumatic-tired roller, whether used for breakdown or subsequent rolling, should continue until tire marks and ruts have been eliminated. Under normal conditions, when a pneumatic-tired roller is on top of a firm mat, it has practically no horizontal thrust on the pavement. The reason is that contrary to the action of a steel wheel, the pneumatic tire flattens on the bottom. This permits an almost 100 percent vertical force.

Several factors affect the performance of a pneumatic-tired roller when it is used for breakdown and compaction. Control of the contact pressure exerted by the pneumatic tires is critical to the best performance of this type of equipment. The most effective tire pressure for the pneumatic roller is the highest pressure that can be used without overstressing the mix. This pressure varies for different mixes, but for normal highway work the maximum pressure is in the range of 90 psi when the tires are hot. This will mean a 70 to 75 psi tire pressure when the tires are cold. The tire pressures may have to be reduced somewhat if the roller is being used on a sandy mix having relatively low stability and cohesion. Commonly, a roller with nine wheels will be used. Seven-wheel and eleven-wheel rollers may also be used successfully with proper adjustment of load and tire pressure. As a rule, the weight per wheel on the roller should not exceed 3,000 to 3,500 pounds. The tire sizes for breakdown compaction require a rim diameter of 20 inches. The most common tire width is 9 inches or occasionally 11 inches. When using a pneumatic-tired roller for the breakdown and compaction of a hot mix, no water should be used on the tires. The tires should be allowed to heat up as rolling progresses. While heating up, the mix may stick somewhat to the tires, however it will gradually be scraped off by the roller pads. As soon as the tires are hot, the mix will no longer stick.

Heat checks in a new asphalt pavement can be healed by the kneading action of rubber tires. A pneumatic-tired roller can provide the necessary kneading effectively during construction or even for several days afterward. In case of delay for a few days, the pavement should be exposed to a hot sun for at least two hours to raise the pavement temperature sufficiently for the pneumatic-tired roller to be effective.

When a pneumatic-tired roller is used for kneading, control of contact pressure is also important for optimum performance. The criteria for kneading a finished asphalt surface are somewhat different, however, from those used in breakdown and compaction. For kneading action, pressure in the tires should be in the range of 50 to 60 psi. The lower tire pressure permits a larger area of tire contact with the pavement surface, and also tends to afford more kneading by the tire than if the tire pressure were higher. A nine-wheel pneumatic-tired roller is the most useful for kneading action, although a seven- or eleven-wheel roller is also satisfactory. The weight per wheel need not be greater than 1,500 to 2,000 pounds. A satisfactory tire size may be a 15 inch, 17 inch, or 20 inch diameter rim. The tire width preferably should be 9 inches but other widths will also work adequately. For greatest effectiveness, the pavement temperatures should be above 100°F before using the roller. At least 8 or 10 coverages should be made over the area to be kneaded.

THE ROLLING PATTERN

The rolling pattern not only includes the number of passes, but also the location of the first pass, the sequence of succeeding passes, and the overlapping between passes. Rolling speed should not exceed about 3 mph. In addition, sharp turns and quick starts or stops are to be avoided. For thin lifts, a recommended rolling pattern for static steel-tired rollers is shown in Figure B10. The rolling operation should start from the edge of the spread on the low side with the roller moving forward as close behind the paver as possible. The second movement of the roller should be to reverse in the same path until the roller has reached previously compacted material. At this point it should swing over and move forward along path number 3 again going as close as possible behind the paver. The fourth movement is reversal in the third path and a repetition of the previous operation. After the entire width of the mix being placed has been covered in this fashion, the roller should swing across the spread to the low side and repeat the process. With this pattern, the lap of the roller with succeeding passes need not be more than 3 to 4 inches.

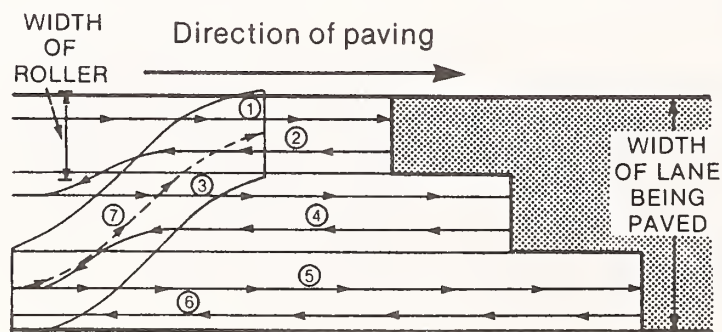


Figure B10.

For thick-lift construction, the rolling process should start 12 to 15 inches from the lower unsupported edge until the center portion of the spread is compacted to some degree of stability. Succeeding passes of the roller should then gradually progress toward the edges of the spread. The uncompacted edge provides initial confinement during the first pass, thus minimizing lateral movement of the mix. After the central portion of the spread has been compacted, the mix will support the roller and allow the edge to be compacted without lateral movement.

COMPACTION WITH VIBRATORY ROLLERS

The specific requirements to achieve density by compaction with vibratory equipment are the same as for static-steel and pneumatic-tired rollers. There must be a firm subgrade, adequate mix confinement, correct workability in the mix, and proper utilization of energy. In the strictest sense, a vibratory roller does not actually compact by vibration, but rather by impact. A rotating eccentric weight in the wheel produces vibration, but the energy imparted to the mix is mainly from impact and weight. Some vibratory energy, however, is imparted to the material particles in the mix. Both the frequency and amplitude of vibration can be adjusted in most vibratory rollers. The amplitude controls the amount of energy imparted to the mix by each up and down movement of the wheel as it vibrates. Frequency controls the number of times per minute that the energy of these downward forces is applied by the vibrating wheel. These impacts produce pressure waves that pass through the mix as shown in Figure B11.

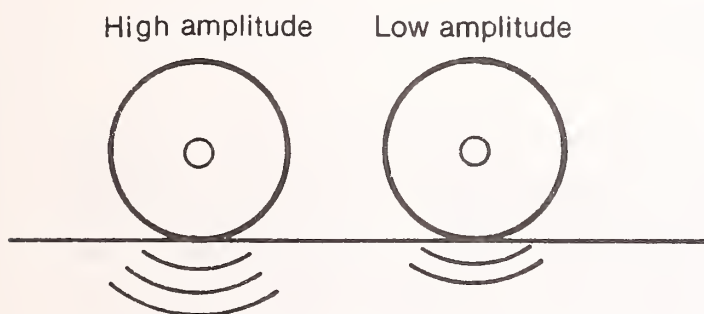


Figure B11.

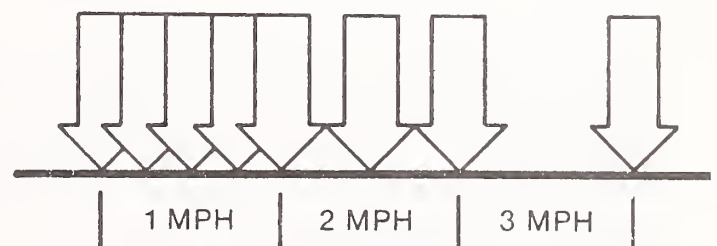


Figure B12.

To ensure smoothness under vibratory compaction, the frequency and roller speed should be matched so that there will be at least ten downward impacts of the vibration per foot of travel of the roller. The relationship between speed and frequency is illustrated in Figure B12. As the speed of the roller increases for a given frequency of vibration, the spacing of the impacts grows

farther apart. In asphalt mixtures, it is generally agreed that the most desirable method is to use the maximum rated frequency with the speed of the roller adjusted to provide the desired impact spacing.

Figure B13 illustrates four different modes of using a vibratory roller equipped with two vibrating wheels. The first mode shows the roller being used without vibration. It simply acts as a static steel-wheeled tandem roller. The second mode shows the use of vibration on the trailing wheel with the leading wheel in the static mode. This mode may be desirable on mixes that have borderline stability. The third mode illustrates the use of vibration with both wheels when being used on a stable mix in order to achieve the maximum compactive energy. The fourth mode illustrates vibration on the leading wheel of the roller and is sometimes used to achieve compaction with this wheel while the trailing wheel in the static condition provides a smoother finish. The selection of the mode of operation should be tailored to the mix being placed and the conditions of the project.

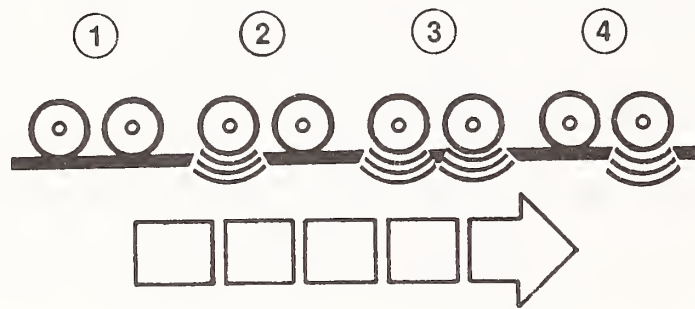


Figure B13.

In utilizing vibratory equipment, keep in mind that the energy imparted by the vibratory wheel must be absorbed in the mix being compacted. Controlling the amplitude permits the operator to vary the force developed from the wheel and, therefore, the energy imparted to the mix. Amplitude adjustments may be necessary for every change in the mix being placed. For example, a change in the lift thickness, mix temperature, mix gradation, filler content, and asphalt content may require adjustment in the amplitudes being used. It is important that the roller should be vibrating only when it is moving. If vibration continues while the roller is standing still or changing direction, each vibrating wheel will leave an indentation in the pavement at the stopping point. Most modern rollers have automatic cut-offs for vibration when the roller stops moving.

Generally, vibration should not be used for compacting thin overlays. This is particularly true with sandy mixes. In thin overlays, there is frequently insufficient material to absorb the energy imparted by the vibrating rollers. The energy therefore passes through the mix being compacted, and rebounds from the surface of the pavement being overlaid. It re-enters the mix being placed, and decompacts it. For situations of this type, the vibratory roller should be used in the static mode. The rolling speed whether being used in the vibratory or static mode, should not exceed 3 mph. This rolling speed is the same as the maximum recommended for static steel-wheeled rollers and pneumatic-tired rollers.

APPENDIX C
BIBLIOGRAPHY

Publications available from The Asphalt Institute.

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- M.S. 1-Thickness Design - Asphalt Pavements for Highways and Streets
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